# THE EFFECT OF LOCAL SCHOOLS TRAFFIC ON CONGESTION OF URBAN NETWORK

BY

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A Thesis Presented to the
DEANSHIP OF GRADUATE STUDIES

**KING FAHD UNIVERSITY OF PETROLEUM & MINERALS**

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

**MASTER OF SCIENCE**

**In**

CIVIL AND ENVIRONMENTAL ENGINEERING

DECEMBER 2013

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN-31261, SAUDI ARABIA

**DEANSHIP OF GRADUATE STUDIES**

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عمادة الدراسات العليا
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In the Name of Allah, Most Gracious, Most Merciful

TO MY BELOVED FATHER,

MOTHER,

WIFE,

& AHMAD

# ACKNOWLEDGMENTS

Acknowledgement is due to King Fahd University of Petroleum and Minerals for supporting this research.

I wish to express my deep appreciation to Prof. Nedal Ratrout, who served as my major advisor, for his valuable advice and suggestions. Also, thanks are due to the other members of my thesis committee, Dr. Shukri Al-Senan and Dr. Khalaf Al-Ofi, for their useful suggestions.

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# ABSTRACT


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Thesis Title : THE EFFECT OF LOCAL SCHOOLS TRAFFIC ON CONGESTION OF URBAN NETWORK

Major Field : TRANSPORTATION ENGINEERING

Date of Degree : DECEMBER 2013

Schools in Saudi Arabia are of three levels: elementary, intermediary and secondary schools. It is thought that most of these schools built several years ago are based on the assumption that majority of its students will be walking to and from the schools since most of these schools were not provided with drop-off/pick-up areas. This research aimed to study the characteristics of trips attracted to local public boys' schools and suggest possible remedies to mitigate their adverse effect on the road network. It was found that the best variables which can be used to predict the number of attracted and parked vehicles are the number of students and number of employees. From the questionnaire analysis, it is obvious that 60% of overall students are suffering from congestion around schools but still 50% of them are coming to schools by passenger cars. Also, more than 60% of the students are ready to use the public transportation. With 33% of overall students ready to use the public transportation if it is free, 27% can pay an average of 50 SR.


**MASTER OF SCIENCE**

**KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS**

**DHAHRAN, SAUDI ARABIA**

# ملخص الرسالة

**الاسم الكامل:** خالد جمال عاصي

**عنوان الرسالة: تأثير الحركة المرورية للمدارس على الازدحام المروري لشبكات الطرق في المدن الحضرية**

**التخصص: هندسة المواصلات**

**تاريخ الدرجة العلمية:** ديسمبر, 2013

تقسم المدارس في المملكة الى ثلاثة مستويات و هي المدارس الابتدائية, المدارس المتوسطة و المدارس الثانوية. يعتقد ان معظم هذه المدارس التي بنيت من عدة سنوات تم بناؤها على افتراض ان غالبية طلابها سوف يعتمدون على المشي كوسيلة للتنقل من و الى المدرسة لأن معظم هذه المدارس لم تزود بمناطق نزول و ركوب الطلاب. هذا البحث يهدف الى دراسة خصائص الرحلات الى لمدارس البنين الحكومية في منطقة الظهران و الخبر واقتراح الحلول الممكنة للتخفيف من تأثيرها السلبي على شبكة الطرق. لقد وجد ان افضل المتغيرات التي يمكن استخدامها للتنبؤ بعدد السيارات المتوقفة و المجذوبة الى المدرسة هي عدد الطلاب و عدد الموظفين. تظهر نتائج تحليل الاستبيانات ان 60% من العدد الكلي للطلاب يعانون من الازدحام حول المدارس و لكن لا يزال 50% منهم يأتون الى المدارس بالمركبات. بالاضافة الى ذلك, 60% من عدد الطلاب الكلي مستعدون لاستخدام و سائل النقل العام بحيث 33% من عدد الطلاب الكلي مستعدون لاستخدام و سائل النقل العام اذا كانت من دون مقابل و 27% من عدد الطلاب الكلي على استعداد لدفع بما متوسطه 50 ريال سعودي كحد اعلى مقابل هذه الخدمة.

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**DHAHRAN, SAUDI ARABIA**

# CHAPTER 1

# INTRODUCTION AND LITERATURE REVIEW

## 1.1 Introduction

The main adverse effects of congestion of urban networks are slower speeds, increased travel times and queuing. This affects negatively the economy and prosperity of any nation. Congestion also has adverse impacts on safety and quality of life. Even if traffic along the road network is acceptable at the present time, congestion is usually expected in the future due to natural growth of the population [1]. Major traffic generators such as malls, hospitals and schools contribute significantly to urban congestion. This research aimed to study and understand the trip attraction of public schools, and ultimately suggests some remedies to mitigate its contribution to urban congestion in the study area.

## 1.2 Problem Statement

Schools in Saudi Arabia are of three levels: elementary, intermediary and secondary schools. Most of these schools built several years ago are based on the assumption that the majority of its students will be walking to and from the schools since most of these schools were not provided with drop off/pick up areas. Consequently, the possible problem associated with vehicles congestion and parking demand was not taken seriously by the planners at that time. Unfortunately, nowadays one can easily observe that the majority of school trips are undertaken by vehicles in general and by passenger cars in particular. It looks like that the major reasons for this shift to vehicular trips are the financial status of the population and the extremely poor public transit transportation system of the country. This research aimed to study the characteristics of trips attracted to local public schools and their effect on the surrounding road network, and ultimately suggests possible remedies to mitigate their adverse effect on the road network. This study focused on public schools since they constitute about 66% of the school population in the study area, and because their students usually share common socioeconomic characteristics. The study focused only on the AM peak at schools since it is the most critical peak period. The PM peak (at school closure) is not critical as the AM peak since a considerable number of schools and different classes within the same schools end at different times. Therefore, departure times at all schools are spread over long time periods to lessen the effect of congestion. This also makes manual data collection in the afternoon extremely hard.

## 1.3 Objectives

The specific objectives of this research were as follows:

1. To study the characteristics of the attracted trips to local public schools.
2. To investigate the socioeconomic factors of students that may affect the trip attraction to boys' public schools in the study area.
3. To develop trip and parking generation models to understand the traffic impact of boys' public schools that can be used locally to predict the vehicle trips attracted to public schools.
4. To test the developed model on samples of public schools in the local area.

5. To review possible methodologies and techniques which are promising in mitigating the problem of congestion around schools.
6. To assess the acceptance of some of these methodologies by students and their parents by conducting a questionnaire survey.

## 1.4 Literature Review

Increase in demand for transportation plays a leading role in creating congestion in urban areas. Economic growth and social development increase mobility in cities and promote the use of private vehicles. People need or desire access to numerous activities in more complex urban environments, therefore, an increase in demand for transportation is inevitable. However, transportation infrastructure is limited and is not always used in an optimal fashion. There are number of factors influencing demand for travel and result in congestion in the short or long run, such as [1]:

- Socioeconomic growth.
- Increase in urban population.
- Car ownership and dependency.
- Land uses.
- Travel patterns.
- Public transport operations.
- Urban freight transport and goods delivery.
- Parking.

Saudi Arabia has experienced a rapid economic growth since the oil boom, resulting in a dramatic increase in the number of registered vehicles from 144,768 in 1970 to 12,895,705 in 2010 according to the available most recent data [2]. This growth in motorization was accompanied with an increase in the size of the road network in the Kingdom. As a result of this remarkable growth in motorization and the road network size, traffic accidents and congestion have become a serious problem facing this country. The number of traffic accidents in 2011 was 544,179 accidents with a total number of 7153 fatalities according to the available most recent data [3]. Trip generation rates from elementary, middle and high schools have all increased noticeably over the past years because of several factors such as reduced walking and biking as well as reduced school bus programs. The Trip Generation report, 8th Edition of 2008 [4] estimates that elementary schools generate about 1.29 trip ends per student per weekday, with 0.45 during the AM peak hour and 0.28 during the afternoon peak hour. This is a significant increase from the rate of 1.02 trip ends per student per weekday, with 0.30 during the AM peak hour and 0.26 during the afternoon peak hour in Trip Generation report, 6th Edition, 1997 [5]. The main independent variables in ITE (Institute of Transportation Engineers) are the number of students, the number of employees and gross floor area.

According to the Trip Generation report, 8th Edition [4], the best fit regression curves are accepted for any land use only when each of the following three conditions is met:

1- The $R^2$ is greater than or equal to 0.50.
2- The sample size is greater than or equal to 4.
3- The number of trips increases as the size of the independent variable increases [4].

Trip generation manual for Riyadh city provides the trip rates for different land uses in Riyadh. The minimum sample size used to predict the trip rates for any level of public schools is 21 schools.

The trip rates for morning peak hour of each level of schools and independent variables for different manuals used are shown in Tables 1.1 to 1.8 [6].

**Table 1.1: Riyadh trip rates for secondary public schools (boys and girls) (morning peak)**

| Independent variable | Sample size | Average rate | Regression model | $R^2$ |
|---|---|---|---|---|
| Total Floor Area ($m^2$) | 24 | 0.116 | y= 0.101x+47.5 | 0.50 |
| Number of Students | | 0.654 | y=0.7609x-60.7 | 0.58 |

**Table 1.2: Riyadh trip rates for intermediary public schools (boys and girls) (morning peak)**

| Independent variable | Sample size | Average rate | Regression model | $R^2$ |
|---|---|---|---|---|
| Number of Students | 31 | 0.75 | y=0.5884x+78.1 | 0.68 |

**Table 1.3: Riyadh trip rates for primary public schools (boys and girls) (morning peak)**

| Independent variable | Sample size | Average rate | Regression model | $R^2$ |
|---|---|---|---|---|
| Total Floor Area ($m^2$) | 22 | 0.117 | y= 0.056x+145.4 | 0.50 |
| Number of Students | | 0.66 | y=0.748x-45.3 | --- |
| Number of Teachers | | 9.96 | y=6.227x+126.7 | 0.79 |

*Source*: *The Ministry of Municipal and Rural Affairs, Saudi Arabia, Trip Generation Manual for Riyadh City, 2009 [6].*

**Table 1.4: ITE trip rates for secondary schools (morning peak)**

| Independent variable | Number of studies | Average rate | Regression model | $R^2$ |
|---|---|---|---|---|
| Number of Students | 68 | 0.42 | Not given | Not given |
| Number of Employees | 53 | 4.68 | Not given | Not given |
| 1000 sq. ft. Gross Floor Area | 44 | 3.06 | Not given | Not given |

**Table 1.5: ITE trip rates for intermediary schools (morning peak)**

| Independent variable | Number of studies | Average rate | Regression model | $R^2$ |
|---|---|---|---|---|
| Number of Students | 25 | 0.54 | Not given | Not given |
| Number of Employees | 21 | 5.30 | $y=9.25x-300.80$ | 0.54 |
| 1000 sq. ft. Gross Floor Area | 21 | 4.35 | Not given | Not given |

**Table 1.6: ITE trip rates for primary schools (morning peak)**

| Independent variable | Number of studies | Average rate | Regression model | $R^2$ |
|---|---|---|---|---|
| Number of Students | 48 | 0.45 | $Ln(Y) = 1.14Ln(X)-1.86$ | 0.50 |
| Number of Employees | 50 | 5.37 | $Y = 7.91x-127.63$ | 0.66 |
| 1000 sq. ft. Gross Floor Area | 58 | 5.20 | $Ln(Y) = 1.20Ln(X)+0.66$ | 0.63 |

*Source*: *Institute of Transportation Engineers, Trip Generation, 8th edition, 2008 [4].*

**Table 1.7: Dubai trip rates for secondary schools (morning peak)**

| Independent variable | Number of studies | Average rate | Regression model | $R^2$ |
|---|---|---|---|---|
| Number of Students | Not given | 0.52 | Not given | Not given |
| 100 sq. m. Gross Floor Area | Not given | 1.086 | Not given | Not given |

**Table 1.8: Dubai trip rates for primary and intermediary schools (morning peak)**

| Independent variable | Number of studies | Average rate | Regression model | $R^2$ |
|---|---|---|---|---|
| Number of Students | Not given | 0.43 | Not given | Not given |
| 100 sq. m, Gross Floor Area | Not given | 2.750 | Not given | Not given |

*Source: Roads and Transport Authority, G.o.D., Dubai Trip Generation and Parking Rates 2013 [7].*

One of the important types of recurring congestion all over the world is the school-related traffic congestion which has adverse effects on the safety of the students, parents, teachers, motorists and residents [8]. There are many studies about congestion around schools, factors that affect the modal choice of students, and possible solutions to reduce the impact of congestion around schools.

One study which was done at 34 California public elementary schools showed that walking and biking rates in the schools are influenced negatively by school size and positively by neighborhood population density as shown in Figure 1.1 below [9-10].

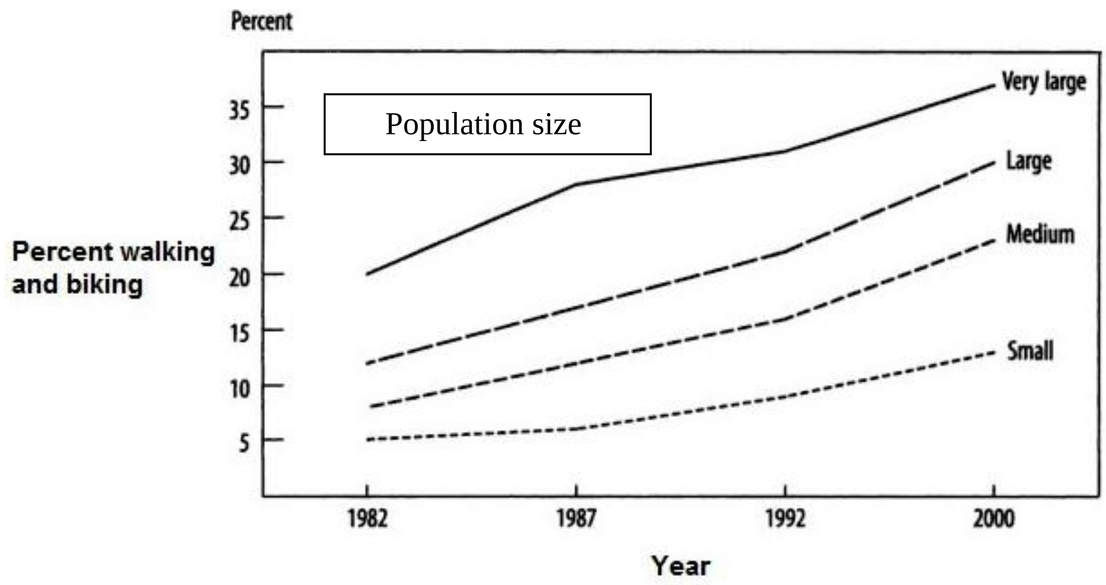



**Figure 1.1: Percent of daily travel in congestion, by regional size group [10]**

Another study which was done by Black et al. [11] found a significant relationship between mode choice and the distance from school to home. They concluded that the probability of traveling by automobile instead of by foot increased from 20% at 0.5 mi distance to 50% at 1.25 mi and 80% at 2 mi.

Cynecki and Brownlee [12] related the reduction in walking and increased congestion around schools to the number of factors such as:

- Increased size of the school: larger population of schools results in larger attendance boundaries with longer walking distances.
- School placement within the attendance boundary: schools must be in the center of the attendance boundary to minimize walking distances.
- Traffic circulation and connectivity: schools should have vehicle access from at least two different streets since more access will result in less congestion and

more efficient traffic operation. The access of pedestrians and bicycles should be provided from all points around the schools.

- Lack of sidewalks: the presence of safe sidewaks around the school will encourage the parents to allow their children to walk to the school.
- Pick-up and drop-off areas for school buses and parents.
- Inadequate parking.
- Teenage drivers at high schools, who are the least experienced drivers, are more prone to crashes.

Another study concluded that the walk travel time is the most significant factor affecting the decision to walk to the school [13].

Slipp and Hummer [14] made a study to determine the trip generation rates for public high schools in North Carolina and compare them with those presented in ITE trip generation report, using students, employees and gross floor area as independent variables. They found that the rates are higher than those of the ITE trip generation. Dean et al. [15] conducted a study to determine the demand for pick-up/drop-off facilities to develop retrofit strategies for existing schools in the city of Surrey in British Colombia and design guidelines for new development. The data collection of the project contained a combination of school site surveys and questionnaires for twenty elementary schools. The number of vehicles arriving and departing was recorded each minute over a period of one hour. The purpose of the questionnaire was to determine the number of vehicles picking up or dropping off by asking the students about the mode they used in coming to the school. Various trend types (linear, logarithmic, power and exponential) were checked using the number of students as an independent variable. It was concluded that the best model is the power trend type since it has the highest $R^2$.

Transportation management strategies generally exclude extensive infrastructure investments aimed at expanding roadway capacity. Instead, these strategies focus on:

1. Management of travel demand to reduce the severity and duration of circumstances where travel demand exceeds existing roadway capacity. Modifications to travel demand can include adjustments to travel time (by time-of-day and/or day-of-week), travel route, trip distance (through changes in trip origins and destinations), and vehicle occupancy.

2. Management of existing corridor capacity to address locations where relatively minor improvements to the roadway network or highway operations will help address temporary or long-term capacity bottlenecks. Temporary bottlenecks include those caused by incidents, weather, and construction factors.

The congestion management system (CMS) is intended to provide information on transportation system performance and identify alternative actions to alleviate congested roadway conditions. Figure 1.2 presents the steps for CMS [16].

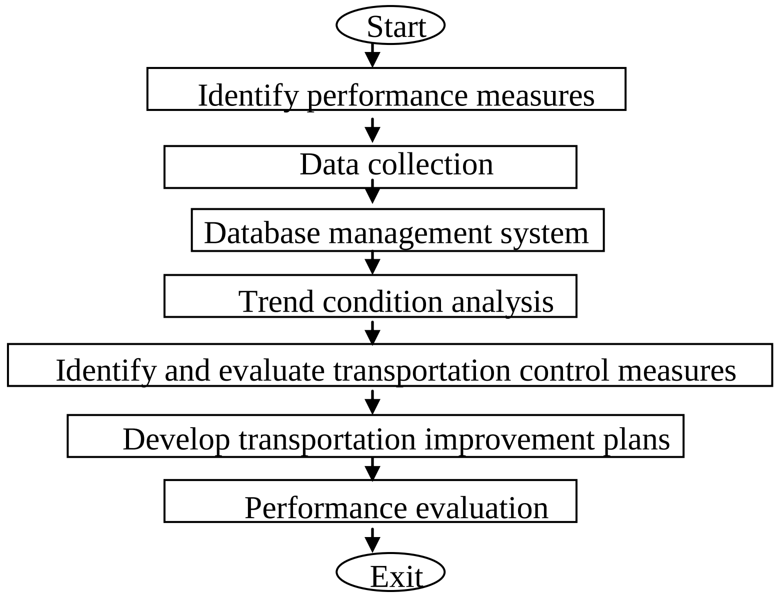



**Figure 1.2: Possible CMS flowchart [16]**

There are three types of measures which are used to reduce congestion in cities:

1- Short-term measures such as:

- Change of traffic signal regulation systems.
- The systems for automatic traffic control (such as changeable message signs).

2- Medium-term measures which include major traffic and technical works that significantly improve the current conditions.

3- Long-term measures that permanently change the current conditions such as construction of new streets [17].

The common reasons which make the parents take their children to school by car are traffic hazards, time constraints, bad weather, and strange danger [18].

The most efficient solution to the problem of traffic congestion around schools is encouraging walking and biking to school by enhancing safety around schools. There are number of factors that affect the overall safety around schools, such as physical setting, school population characteristics, and law enforcement [19].

One of the studies done by Bradshaw [20] in the north-western suburbs of Leeds suggested ways to make walking and cycling more attractive, which can be summarized as follows:

- Provide widened pavement in order to redress the problems caused by children or parents who sometimes have to walk on the road.
- Lessen the numbers of cars within close proximity of the schools by providing traffic free zones around schools.
- Provision of drop-off and collection points for those walking and/or catching buses at which larger groups of children could gather and be walked to the school by a responsible adult.
- Make parents realize that in driving their children to the school, they are contributing to the problems of congestion and road safety.
- Provide cycle lanes to the schools.

According to the Astralian Department of Transport [21], there are several attributes that are extremely important in providing safety around schools, such as:

- Traffic speeds should be low, desirably 40 km/h or less.

- Providing paths on the school side of the road for children walking and cycling.
- Sight lines for drivers to see children and to be seen by children should be clear at intersections and all places where children might cross a road.
- Road crossing places for children should be safely located and adequately signed.
- All pedestrian and bicycle access ways should be free from visibility constraints.

One of the suggested solutions to reduce congestion around schools and encourage walking/biking to school is to enhance safety by implementing safe routes to school (SRTS) programs. Safe Routes to School is a national and international movement to create safe, convenient, and fun opportunities for children to bike and walk to and from the schools. The effectiveness of this technique was measured by Zhao and Zhou [22] with the data collected before and after the implementation of the SRTS programs in Hillsborough County, Florida. He indicated that walking/biking rates improved significantly.

La Vigne [8] suggested specific responses to reduce traffic congestion around schools, such as:

- *Educating parents:* educate parents about their children using alternative transportation modes to and from the school, the dangers and legal consequences of traffic violations as well as the role that parents can play in reducing congestion and increasing student safety by following the rules of the road.
- *Encouraging carpooling.*
- *Mapping out safe pedestrian routes.*

- *Instituting school busing:* this is an effective means of reducing the number of children taken to schools by car.
- *Altering drop-off and pick-up rules:* altering the time during which parents can drop off or pick up their children or by staggering bell times.
- *Strategically funneling traffic:* this is done by directing different types of traffic to different locations around the school property. For instance, locate staff parking in another area for pick-up and drop-off.
- *Establishing parking zones.*
- *Synchronizing traffic signals.*

To enhance the student loading (pick-up and drop-off) efficiency and safety, Qualls [23] suggested to use the automatic barcode reading technology in which the entrance of the school driveway is equipped with a barcode reader that reads a barcode decal on each pick-up vehicle entering the driveway. Then, the students to be picked up are staged in the classroom in succession according to the scans of the barcode decals. Another ITS (Intelligent Transportation Systems) technique suggested by Sarasua et al. [24] is to enhance after-school traffic operation at an elementary school in Clemson, South Carolina. The technology used is the radio frequency identification (RFID) system which provides advanced notification of the approaching vehicles and their intentions so that students could be loaded into cars more efficiently. It was concluded that the usage of this new technology will increase the school's capacity to handle after-school pick-ups by 14%, which results in decreasing the vehicle wait times, shorter queue lengths and more efficient use of passenger pick-up area. Also, one of the most widely used components of ITS is the Advanced Traveler Information System (ATIS). It includes Variable Message

Signs (VMS), route guidance, telephone information, and radio systems. These techniques assist motorists in making more informed decisions to avoid congestion by their pre-route and en-route path selection.

Parking supply and demand management strategies provide efficient solutions to many of the problems facing the transportation system, such as delay reduction, capacity utilization and travel time reliability. Many studies and manuals were conducted and developed to predict the parking demand for different land uses [25]. ITE Parking Generation report provides the parking demand rates for the three levels of schools for different independent variables such as number of students and the number of employees as shown in Table 1.9.

**Table 1.9: Parking demand rates for schools [26]**

| **Level of school** | **Sample size** | **Independent variable** | **Average peak period parking demand** |
|---|---|---|---|
| Elementary | 6 | Students | 0.28 veh/student |
| Middle | Not given | Students<br>Employees | 0.11 veh/student<br>1.2 veh/employee |
| High | 3 | Students | 0.09 veh/student |

*Source: McCourt, Institute of Transportation Engineers, Parking Generation, 3rd Edition, 2004 [26].*

After applying a specific solution to the problem of congestion around schools, some of the measures that can be used to evaluate the effectiveness of this solution are as follows [8]:

- Fewer vehicles around schools.

- Reduced time spent by the parents in dropping off and picking up their children.
- Fewer vehicular crashes around schools.
- Fewer pedestrian injuries and deaths around schools.
- Fewer traffic violations around schools.
- Lower percentage of parents using cars to take their children to the school.
- Improved perceptions of congestion among parents and staff.

In summary, there are different reasons for the congestion around schools, such as school placement, traffic circulation, lack of sidewalks, pick-up and drop-off areas and inadequate parking.  From the literature, there are a wide range of remedies that can be used to reduce congestion around schools, such as:

- Educating parents
- Encouraging carpooling
- Instituting school busing
- Altering drop-off and pick-up times
- Establishing parking zones
- Synchronization of traffic signals

## 1.5 Study Area

This research was conducted on samples of public schools located in Al-Khobar and Dhahran cities in Saudi Arabia. Convenience is the main reason for selecting this area as a case study. The total population of Al-Khobar and Dhahran cities is 587,965 capita [27], which represents nearly 2.2% of the total population of Saudi Arabia. The total number of all levels of public, private and international schools in the study area are presented in Table 1.10 [27].

**Table 1.10: School population in the study area [27]**

| School type | Total number |
|---|---|
| Public Secondary | 18 |
| Public Intermediary | 25 |
| Public Primary | 45 |
| All Private | 45 |
| Total | 133 |

*Source*: *Census Report for 2010 , Saudi Arabia, 2010 [27]*.

This study focused on public schools since they constitute about 66% of the total school population in the study area, and because their students usually share common socioeconomic characteristics.

## 1.6 Data Collection

Because of the lack of financial resources and human manpower, data were collected at only 30 different schools in Al-Khobar and Dhahran cities which represent 34% of public schools via manual traffic counts. All of the schools were selected randomly. All of the businesses conducted at these particular schools occur during the morning peak hour period. Therefore, the trip generation data collection and analysis was limited to the AM peak hour period only. The study focused only on the AM peak at schools since it is the most critical peak period. The PM peak (at school closure) is not critical as the AM peak since a considerable number of schools and different classes within the same school end at different times. Therefore, departure times at all schools are spread over long time periods to lessen the effect of congestion. This also makes manual data collection in the afternoon extremely hard.

All of the data were collected during March and April of 2013 on typical weekdays which are Saturday, Sunday, Monday, Tuesday, Wednesday and Thursday. The number of drop-off and parked vehicles was documented at each of these schools between the hours of 6:15 AM to 7:15 AM, which represents the AM peak hour, since the schools start at 7:00 AM. Figure 1.3 indicates the approximate locations of schools included in this analysis.


**Figure 1.3: Approximate schools locations**

Data for the following variables were considered at all 30 schools included in this study:

- Number of students for each school
- Number of employees for each school
- Number of classes
- Total floor area ($m^2$): the sum (in square meter) of the built area of each floor level.
- Total lot area ($m^2$): defined as the area (in square meter) of the built and unbuilt land owned by the school.
- Airline distance to nearest school (m)
- Airline distance to nearest arterial (m)
- Airline distance to nearest collector (m)
- Airline distance to central business district (m): The CBD or Central Business District is the focal point of a city. It is the commercial, office, retail, and cultural center of the city and usually is the center point for transportation networks. According to the municipality of Al-Khobar, the CBD was presented as a black circle in Figure 1.3. It is hypothesized that as the value of this variable increases, the population density decreases, and consequently, the number of schools are less and the distance between schools will be large, which necessitates vehicular trips rather than walking to school.

The number of students, employees and classes were determined by asking the headmaster directly. The total lot area which represents the built and unbuilt land owned by the school, and the total floor area which represents the area of all buildings of the school, were both determined using the Google Earth software. Also, Google Earth was used to measure all the distances.

The collected data for each level of schools are summarized in a tabulated format as shown in Tables 1.11 to 1.13 below.

**Table 1.11: Collected data for secondary schools**

| Reference number | School | Drop-off vehicles | Parked vehicles | Total Attracted vehicles | Number of Students | Number of Employees | Number of Classrooms | Lot Area ($m^2$) (1000 sq m) | Floor Area ($m^2$) (1000 sq m) | Distance to nearest school (m) | Distance to nearest arterial (m) | Distance to nearest collector (m) | Distance to CBD (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Al-Kisa'i | 68 | 131 | 290 | 864 | 51 | 23 | 10.36 | 5.40 | 1364 | 25 | 40 | 2614 |
| 2 | Al-Thuqba | 89 | 70 | 240 | 721 | 45 | 21 | 14.25 | 5.70 | 1335 | 1115 | 44 | 1828 |
| 3 | Ibn Senaa' | 191 | 72 | 250 | 537 | 55 | 19 | 11.50 | 8.4 | 1667 | 100 | 50 | 1651 |
| 4 | Al-Oroba | 84 | 73 | 157 | 310 | 24 | 9 | 13.30 | 5.84 | 4803 | 510 | 435 | 8200 |
| 5 | Al-Khobar | 150 | 109 | 235 | 500 | 53 | 13 | 19.364 | 6.80 | 130 | 440 | 65 | 741 |
| 6 | Al Ya'qobi | 70 | 51 | 121 | 293 | 37 | 12 | 10 | 3.227 | 130 | 440 | 65 | 830 |
| 7 | Ibn Al-Qassem | 68 | 39 | 107 | 191 | 30 | 6 | 6.43 | 3.638 | 1226 | 210 | 150 | 1138 |
| 8 | Jabal Al-Noor | 144 | 114 | 245 | 448 | 48 | 10 | 9.25 | 5.775 | 3149 | 910 | 294 | 3512 |
| 9 | Al-Khozama | 88 | 84 | 172 | 251 | 30 | 9 | 5.265 | 4.80 | 4201 | 574 | 412 | 7829 |
| 10 | Tayba | 61 | 70 | 149 | 414 | 32 | 13 | 7.60 | 3.23 | 120 | 20 | 40 | 2336 |
| | Average | 101 | 81 | 196.6 | 452.9 | 13.5 | 40.5 | 10.73 | 5.28 | 1812 | 434 | 160 | 3068 |
| | **Range** | **61-191** | **39-131** | **107-290** | **191-864** | **24-55** | **6-23** | **6.43-19.364** | **3.22-8.4** | **120-4803** | **20-1115** | **40-435** | **741-8200** |
| | **Coefficient of variation** | **0.44** | **0.35** | **0.32** | **0.47** | **0.28** | **0.42** | **0.39** | **0.31** | **0.88** | **0.80** | **0.95** | **0.85** |

*Arterial is any divided two-way road with at least two lanes in each direction or higher classification.
Drop-off vehicles: the number of vehicles which came to drop the students and left.
Parked vehicles: is the number of vehicles which parked near the school for school purposes.
Total attracted vehicles: is the summation of drop-off vehicles and parked vehicles.

**Table 1.12: Collected data for intermediary schools**

| Reference number | School | Drop-off vehicles | Parked vehicles | Total Attracted vehicles | Number of Students | Number of Employees | Number of Classrooms | Lot Area ($m^2$) (1000 sq m) | Floor Area ($m^2$) (1000 sq m) | Distance to nearest school (m) | Distance to nearest arterial (m) | Distance to nearest collector (m) | Distance to CBD (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | Al-Khobar | 285 | 48 | 333 | 512 | 52 | 15 | 19 | 5.68 | 900 | 305 | 125 | 1910 |
| 12 | Ibn-Muthaffar | 279 | 42 | 321 | 590 | 48 | 15 | 15.328 | 4.90 | 2226 | 750 | 350 | 8607 |
| 13 | Al-Farabi | 226 | 35 | 261 | 422 | 46 | 15 | 14.042 | 5.33 | 976 | 337 | 157 | 2330 |
| 14 | Ashbielia | 168 | 42 | 270 | 470 | 40 | 23 | 5.49 | 4.44 | 903 | 340 | 30 | 1667 |
| 15 | Ibn Al-Awwam | 157 | 38 | 240 | 417 | 42 | 15 | 13 | 4.20 | 1530 | 213 | 44 | 874 |
| 16 | Eskan Al-Khobar | 58 | 38 | 150 | 375 | 40 | 14 | 7.15 | 3.576 | 562 | 528 | 50 | 2543 |
| 17 | Al-Qadessiyya | 39 | 18 | 57 | 200 | 18 | 10 | 2.295 | 0.765 | 1507 | 116 | 45 | 2317 |
| 18 | Al-Jesser | 130 | 30 | 160 | 280 | 21 | 7 | 5.265 | 1.80 | 905 | 610 | 412 | 7829 |
| 19 | Al-Thuqba | 171 | 28 | 199 | 389 | 37 | 10 | 11.10 | 4.10 | 1120 | 600 | 110 | 1176 |
| 20 | Al-Dhahran | 195 | 28 | 223 | 375 | 36 | 12 | 11.75 | 3.30 | 564 | 1150 | 125 | 5863 |
| | Average | 171 | 35 | 221 | 403 | 14 | 38 | 10.44 | 3.809 | 1119 | 495 | 145 | 3511 |
| | **Range** | **39-285** | **18-48** | **57-333** | **200-590** | **21-52** | **7-23** | **2.295-15.328** | **0.765-5.68** | **562-2226** | **213-1150** | **30-350** | **874-8607** |
| | **Coefficient of variation** | **0.48** | **0.25** | **0.38** | **0.27** | **0.29** | **0.32** | **0.50** | **0.40** | **0.43** | **0.58** | **0.87** | **0.77** |

*Arterial is any divided two-way road with at least two lanes in each direction or higher classification.
Drop-off vehicles: the number of vehicles which came to drop the students and left.
Parked vehicles: is the number of vehicles which parked near the school for school purposes.
Total attracted vehicles: is the summation of drop-off vehicles and parked vehicles.

**Table 1.13: Collected data for primary schools**

| Reference number | School | Drop-off vehicles | Parked vehicles | Total Attracted vehicles | Number of Students | Number of Employees | Number of Classrooms | Lot Area ($m^2$) (1000 sq m) | Floor Area ($m^2$) (1000 sq m) | Distance to nearest school (m) | Distance to nearest arterial (m) | Distance to nearest collector (m) | Distance to CBD (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | Ubai Ibn Thabet | 229 | 40 | 260 | 410 | 43 | 20 | 18.594 | 4.18 | 1323 | 722 | 206 | 8702 |
| 22 | Al-Abbas | 111 | 44 | 170 | 430 | 45 | 21 | 8.231 | 3.30 | 532 | 145 | 45 | 1803 |
| 23 | Al-Seddeq | 205 | 30 | 220 | 375 | 31 | 15 | 11.66 | 3.141 | 925 | 236 | 70 | 1762 |
| 24 | Ubai Ibn Kaab | 129 | 27 | 156 | 311 | 28 | 14 | 2.299 | 1.584 | 507 | 328 | 30 | 1003 |
| 25 | Hitteen | 109 | 45 | 250 | 658 | 48 | 26 | 6.636 | 3.661 | 87 | 223 | 42 | 2565 |
| 26 | Yohai ibn Mo'en | 84 | 16 | 100 | 203 | 17 | 8 | 0.284 | 0.284 | 3441 | 272 | 694 | 8524 |
| 27 | Hajr | 50 | 10 | 60 | 115 | 12 | 6 | 2.58 | 1.485 | 1592 | 250 | 130 | 3357 |
| 28 | Mohammadia | 136 | 29 | 165 | 440 | 32 | 18 | 3.769 | 3.136 | 443 | 30 | 31 | 1098 |
| 29 | Muath Ibn Jabal | 93 | 20 | 113 | 188 | 20 | 7 | 5.106 | 1.592 | 507 | 435 | 35 | 1330 |
| 30 | Dhahran | 188 | 35 | 223 | 420 | 37 | 18 | 10.144 | 4.042 | 575 | 1310 | 747 | 5740 |
| | Average | 133 | 30 | 172 | 355 | 15 | 31 | 6.93 | 2.64 | 993 | 395 | 203 | 3588 |
| | **Range** | **50-229** | **10-45** | **60-260** | **115-658** | **12-48** | **6-26** | **0.284-18.594** | **0.284-4.18** | **87-3441** | **30-1310** | **30-747** | **1003-8524** |
| | **Coefficient of variation** | **0.43** | **0.40** | **0.39** | **0.44** | **0.39** | **0.43** | **0.79** | **0.50** | **0.93** | **0.89** | **1.30** | **0.80** |

*Arterial is any divided two-way road with at least two lanes in each direction or higher classification.
Drop-off vehicles: the number of vehicles which came to drop the students and left.
Parked vehicles: is the number of vehicles which parked near the school for school purposes.
Total attracted vehicles: is the summation of drop-off vehicles and parked vehicles.

## 1.7 Methodology

The ultimate objective was to evaluate the traffic impact of schools, and this was accomplished in three parts. The first part was modeling of trip and parking generation to estimate the traffic generated in the school, which can help in avoiding the problem of congestion around the proposed schools by providing them with adequate facilities, such as pickup/drop-off areas, parking lots and wider surrounded roads. On the other hand, it can help in predicting the number of attracted vehicles to the existing schools using the rates only rather than counting the number of vehicles. This was conducted by observing the number of vehicular trips and relating it to the number of factors, such as number of students, number of employees, number of classrooms and floor area. The second part was assessing the acceptance by students and their parents of some of the remedies for mitigating congestion around the existing schools. These remedies were taken from extensive literature review about the problem of congestion around schools and the suggested remedies to solve this problem. Some of these remedies which were suggested in the literature are as follows:

- Instituting school busing
- Providing parking lots
- Segregation times for the start of the schools
- Distance learning
- Encourage students to walk by providing safe routes to the school

This part was mainly conducted via questionnaire distributed to the students and their parents to assess the acceptance of such remedies as seen by the students and their parents. The final stage was an engineering exercise to show and prove that a simple straightforward engineering solution, such as optimizing signal timing plan at intersections near schools, can reduce congestion considerably. The detailed methodology for conducting these parts is as follows:

1. Identify and determine the public school population in the study area.
2. Conduct a literature review of all possible remedies to mitigate the adverse effect of schools on congestion of urban networks.
3. Select a representative sample.
4. Study the trip attraction characteristics through manual counting of vehicles attracted to schools.
5. Conduct a survey questionnaire on students to study the socioeconomic characteristics of students which might affect the trip making characteristics.
6. Study the traffic peaking characteristics of a sample of major streets surrounding some of the studied schools through automatic traffic counts.
7. Conduct a questionnaire survey with students' parents to evaluate the appropriateness of some remedies in alleviating school congestion in the study area.
8. Draw up conclusions and recommendations.

# CHAPTER 2

# MODELING OF VEHICULAR TRIPS ATTRACTION

## 2.1 Data Analysis and Discussion

Regression analysis is a statistical tool for the investigation of relationships between variables. Usually, the investigator seeks to ascertain the causal effect of one variable upon another.

In this study, single and multiple regressions were used to develop a model which predicts the number of attracted vehicles to schools using many of the dependent variables.

### 2.1.1 Experimental Design

A set of explanatory factors summarizing the characteristics of schools was evaluated. The relationship between these explanatory variables and the number of attracted vehicular trips (dependent variable) was thoroughly investigated through regression. The explanatory variables are of two types:

1. Variables which describe the characteristics of the school:
   - The number of students
   - The number of employees

- The number of classrooms
- Total floor area: the sum (in square meter) of the area of each floor level
- Total lot area: defined as the area (in square meter) of the built and unbuilt land owned by the school

2. Variables which describe the accessibility to school:
   - Airline distance to the nearest school
   - Airline distance to the nearest collector
   - Airline distance to the nearest arterial
   - Airline distance to central business district (CBD)

For each dependent variable, the analysis was done four times for each level of schools as described below:

1. Data analysis for seven schools with intercept
2. Data analysis for seven schools without intercept
3. Data analysis for ten schools with intercept
4. Data analysis for ten schools without intercept

The purpose of analyzing seven schools out of ten is to use the remaining three schools in the validation process which can help in determining the best fit models. For each level of schools, the models which resulted from analyzing seven schools were compared with those that resulted from analyzing ten schools.

The same procedure was done when all schools were pooled together as described below:

1. Data analysis for 21 schools with intercept
2. Data analysis for 21 schools with intercept using two dummy variables to distinguish between the three levels of schools
3. Data analysis for 21 schools without intercept
4. Data analysis for 21 schools without intercept using two dummy variables to distinguish between the three levels of schools
5. Data analysis for 30 schools with intercept
6. Data analysis for 30 schools with intercept using two dummy variables to distinguish between the three levels of schools
7. Data analysis for 30 schools without intercept
8. Data analysis for 30 schools without intercept using two dummy variables to distinguish between the three levels of schools.

The data were analyzed using the SPSS software.

### 2.1.2 Data Analysis for Secondary Schools

#### *2.1.2.1 Summary of Results*

The correlation between the dependent variable (total attracted vehicles) and independent variables for secondary schools was introduced by the following matrix (Table 2.1).

**Table 2.1: Correlation matrix for the variables of secondary schools (10 schools)**

| | *Total Attracted vehicles* | *Number of Students* | *Number of Class-rooms* | *Number of Employees* | *Lot area (per 1000 sqm)* | *Floor area (per 1000 sqm)* | *Parking space* | *Dist to nearest school m* | *Dist to highway m* | *Dist to collector m* | *Dist to CBD m* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Attracted | 1.00 | | | | | | | | | | |
| Students | 0.87 | 1.00 | | | | | | | | | |
| Classes | 0.76 | 0.94 | 1.00 | | | | | | | | |
| Employees | 0.84 | 0.72 | 0.68 | 1.00 | | | | | | | |
| Lot area | 0.44 | 0.42 | 0.36 | 0.50 | 1.00 | | | | | | |
| Floor area | 0.72 | 0.43 | 0.42 | 0.66 | 0.58 | 1.00 | | | | | |
| Parking space area | 0.50 | 0.43 | 0.47 | 0.33 | 0.36 | 0.35 | 1.00 | | | | |
| Dist to nearest school | 0.01 | -0.26 | -0.34 | -0.40 | -0.23 | 0.23 | 0.12 | 1.00 | | | |
| Dist to highway | 0.14 | 0.02 | -0.08 | 0.02 | 0.24 | 0.11 | 0.21 | 0.34 | 1.00 | | |
| Dist to collector | -0.29 | -0.57 | -0.66 | -0.59 | -0.27 | 0.00 | 0.01 | 0.91 | 0.35 | 1.00 | |
| Dist to CBD | -0.12 | -0.30 | -0.34 | -0.57 | -0.26 | 0.04 | 0.25 | 0.92 | 0.20 | 0.89 | 1.00 |

From the correlation matrix, it is clear that the most significant variables which have a strong linear relationship with the dependent variable are the number of students, classrooms, employees and floor area.

The relationships between the dependent variable y (total attracted vehicles) and independent variables for secondary schools are summarized in Tables 2.2 to 2.5 as shown below.

**Table 2.2: Summary of the developed models with intercept for 7 secondary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.2716*Students+67.479 | 0.84 | 780 |
| Attracted vehicles = 4.8691*Employees-5.1964 | 0.62 | 1894 |
| Attracted vehicles = 9.8685*Classes+54.793 | 0.75 | 1252 |
| Attracted vehicles = 27.971*Floor area+44.14 | 0.39 | 3081 |
| Attracted vehicles = 8.05*Lot area+101.96 | 0.05 | 4752 |
| Attracted vehicles = -0.0045*Distance to nearest school+206.86 | -0.19 | 5972 |
| Attracted vehicles = -0.0121*Distance to nearest arterial+201.91 | -0.20 | 6009 |
| Attracted vehicles = -0.2385*Distance to nearest collector+227.4 | 0.098 | 4534 |
| Attracted vehicles = -0.0026*Distance to CBD+206.29 | -0.19 | 5977 |
| Attracted vehicles = 7.48+0.226*Students+14.77*Floor area | 0.97 | 132 |

**Table 2.3: Summary of the developed models without intercept for 7 secondary schools (Trip Attraction)**

| **Model** | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|
| Attracted vehicles = 0.3855*Students | 0.80 | 1585 |
| Attracted vehicles = 4.7539*Employees | 0.80 | 1580 |
| Attracted vehicles = 13.073*Classes | 0.80 | 1532 |
| Attracted vehicles = 35.26*Floor area | 0.78 | 2749 |
| Attracted vehicles = 15.703*Lot area | 0.74 | 5014 |
| Attracted vehicles = 0.0665*Distance to nearest school | 0.27 | 28805 |
| Attracted vehicles = 0.2862* Distance to nearest arterial | 0.34 | 25135 |
| Attracted vehicles = 0.5778*Distance to nearest collector | 0.075 | 39215 |
| Attracted vehicles = 0.0398*Distance to CBD | 0.256 | 29829 |
| Attracted vehicles = 0.228*Students+15.82*Floor area | 0.80 | 112 |

**Table 2.4: Summary of the developed models with intercept for 10 secondary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.2558*Students+80.745 | 0.72 | 1103 |
| Attracted vehicles = 4.7015*Employees+6.19 | 0.67 | 1309 |
| Attracted vehicles = 8.3744*Classes+83.546 | 0.52 | 1903 |
| Attracted vehicles = 27.67*Floor area+50.472 | 0.46 | 2122 |
| Attracted vehicles = 6.71*Lot area+124.56 | 0.10 | 3558 |
| Attracted vehicles = 0.0005*Distance to nearest school+195.70 | -0.12 | 4431 |
| Attracted vehicles = 0.0236*Distance to nearest arterial+186.35 | -0.10 | 4346 |
| Attracted vehicles = -0.1097*Distance to nearest collector+213.61 | -0.03 | 4069 |
| Attracted vehicles = -0.0027*Distance to CBD+204.91 | -0.11 | 4370 |
| Attracted vehicles = 18.76+0.201*Students+16.41*Floor area | 0.87 | 503 |

**Table 2.5: Summary of the developed models without intercept for 10 secondary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.4046*Students | 0.84 | 2180 |
| Attracted vehicles = 4.8445*Employees | 0.86 | 1166 |
| Attracted vehicles = 13.717*Classes | 0.83 | 2752 |
| Attracted vehicles = 36.47*Floor area | 0.84 | 2112 |
| Attracted vehicles = 16.94*Lot area | 0.77 | 5210 |
| Attracted vehicles = 0.061*Distance to nearest school | 0.41 | 22639 |
| Attracted vehicles = 0.284*Distance to nearest arterial | 0.48 | 19069 |
| Attracted vehicles = 0.5776*Distance to nearest collector | 0.27 | 29016 |
| Attracted vehicles Y = 0.0362*Distance to CBD | 0.39 | 23391 |
| Attracted vehicles = 0.208*Students+19.12*Floor area | 0.86 | 473 |

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of ten schools without intercept were used as the final results to make it easier to compare with the international models which use ratios in most situations.

### *2.1.2.2 Models Validation*

The remaining three schools which were not included in developing the models of seven schools without intercept were used to validate these models. Table 2.6 includes the observed values of dependent variable in the first column and the predicted values by the developed models of seven schools without intercept in the other columns.

**Table 2.6: Predicted values by different variables using the developed models (Secondary, Trip Attraction)**

| **Number of attracted vehicles to school** | Students (difference) | Employees (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) | Students + Floor Area (difference) |
|---|---|---|---|---|---|---|
| Coefficient | 0.39 | 4.75 | 13.10 | 35.26 | 15.7 | 0.228, 15.82 |
| 245 | 173(-29%) | 228(-7%) | 131(-47%) | 204(-17%) | 145(-41%) | 194(-21%) |
| 172 | 97(-44%) | 142(-17%) | 118(-31%) | 169(-2%) | 83(+52) | 133(-22%) |
| 149 | 159(+7%) | 152(+2%) | 170(+14%) | 114(-23%) | 119(-20%) | 146(-2%) |
| **Average difference %** | 27 | 8.5 | 26 | 14 | 38 | 15 |
| **Range** | 7-44 | 1-18 | 16-38 | 2-23 | 20-52 | 0-22 |

*CV: coefficient of variation = Standard deviation / Mean*

$$\textit{Difference} = \frac{\text{Predicted value} - \text{Observed value}}{\text{Observed value}} * 100\%$$

### *2.1.2.3 Discussion*

By comparing the models which resulted from the seven schools regression with those that resulted from ten schools analysis, it can be concluded that the developed models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of ten schools analysis. In addition to that, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of attracted vehicular trips to school when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which measures the average of the squares of the "errors" [28]. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

Based on Table 2.5 which summarized the results of analysis of ten schools without intercept and Table 2.6 which contains the predicted numbers of attracted vehicles using the developed models, the best multiple and simple regression models with the lowest mean square residual that explains the attraction behavior to secondary schools are as follows:

**Model A: number of attracted vehicles = 0.208*Students+19.12*Floor Area**

**Model B: number of attracted vehicles = 4.84 * Number of Employees**

The models have the smallest mean square residual. The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the number of students, the plot of residuals against the total floor area, and the normality plot of residuals. All assumptions seemed to be reasonable.

The other models which are significant in predicting the number of attracted trips to secondary schools were arranged in order (from the smallest mean square error to the largest one) as follows:

**Model C: number of attracted vehicles = 36.47 * Total Floor area**

**Model D: number of attracted vehicles = 0.40 * Number of Students**

**Model E: number of attracted vehicles = 13.72 * Number of Classes**

**Model F: number of attracted vehicles = 16.94 * Total Lot Area**

The characteristics of these models are summarized in Table 2.7.

Table 2.7: Characteristics of the developed models (Secondary, Trip Attraction)

| Model number | Variable(s) | Coefficients | P-Value | **Mean square residual** |
|---|---|---|---|---|
| A | Students<br>Floor Area | 0.208<br>19.12 | 4.7E-04<br>4.1E-04 | 473 |
| B | Employees | 4.84 | 1.58E-08 | 1166 |
| C | Floor Area | 36.47 | 2.30E-07 | 2112 |
| D | Students | 0.40 | 2.66E-07 | 2188 |
| E | Classes | 13.72 | 7.62E-07 | 5210 |
| F | Lot Area | 16.94 | 3.0E-04 | 2752 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the independent variables and the normality plot of residuals. All assumptions seemed to be reasonable.

It is obvious that the worst models are those models that depend on the accessibility factors, such as distance to nearest school, nearest arterial, nearest collector, and distance to CBD since they have the highest mean square residual and lowest F-value, which means that the accessibility factors are not significant in determining the number of attracted vehicles to schools.

### 2.1.3 Data Analysis for Intermediary Schools

#### *2.1.3.1 Summary of Results*

The correlation between the dependent variable (total attracted vehicles) and independent variables for intermediary schools was introduced by the following matrix (Table 2.8).

**Table 2.8: Correlation matrix for the variables of intermediary schools (10 schools)**

| | *Total Attracted vehicles* | *Number of Students* | *Number of Class-rooms* | *Number of Employees* | *Lot area (per 1000 sqm)* | *Floor area (per 1000 sqm)* | *Parking space* | *Dist to nearest school m* | *Dist to highway m* | *Dist to collector m* | *Dist to CBD m* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Attracted | 1.00 | | | | | | | | | | |
| Students | 0.94 | 1.00 | | | | | | | | | |
| Classrooms | 0.64 | 0.73 | 1.00 | | | | | | | | |
| Employees | 0.88 | 0.91 | 0.65 | 1.00 | | | | | | | |
| Lot area | 0.83 | 0.76 | 0.25 | 0.85 | 1.00 | | | | | | |
| Floor area | 0.91 | 0.89 | 0.64 | 0.97 | 0.83 | 1.00 | | | | | |
| Parking space area | 0.49 | 0.54 | 0.09 | 0.74 | 0.80 | 0.66 | 1.00 | | | | |
| Dist to nearest school | 0.17 | 0.30 | 0.17 | 0.08 | 0.18 | 0.04 | 0.02 | 1.00 | | | |
| Dist to highway | 0.16 | 0.17 | -0.16 | 0.05 | 0.17 | 0.02 | 0.32 | -0.21 | 1.00 | | |
| Dist to collector | 0.24 | 0.19 | -0.27 | -0.06 | 0.18 | -0.01 | -0.05 | 0.27 | 0.44 | 1.00 | |
| Dist to CBD | 0.09 | 0.11 | -0.19 | -0.18 | 0.01 | -0.21 | -0.10 | 0.26 | 0.65 | 0.86 | 1.00 |

From the correlation matrix, it is clear that the most significant variables which have a strong linear relationship with the dependent variable are the number of students, classrooms, employees, lot area and floor area.

The relationships between the dependent variable y (total attracted vehicles) and independent variables for intermediary schools are summarized in Tables 2.9 to 2.12 as shown below.

**Table 2.9: Summary of the developed models with intercept for 7 intermediary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.761*Students-91.495 | 0.88 | 1137 |
| Attracted vehicles = 8.2*Employees-101.71 | 0.81 | 1798 |
| Attracted vehicles = 15.95*Classes+54.793 | 0.30 | 6705 |
| Attracted vehicles = 56.076*Floor area+1.70 | 0.86 | 1395 |
| Attracted vehicles = 13.50*Lot area+85.98 | 0.62 | 3657 |
| Attracted vehicles = 0.0235*Distance to nearest school+204.31 | -0.18 | 11354 |
| Attracted vehicles = 0.21*Distance to nearest arterial+155.75 | 0.04 | 9243 |
| Attracted vehicles = 0.51*Distance to nearest collector+177.31 | 0.25 | 7212 |
| Attracted vehicles = 0.011*Distance to CBD+199.87 | -0.09 | 10504 |
| Attracted vehicles = -118.74+13.77*Classes+12.44*Lot area | 0.988 | 111 |

**Table 2.10: Summary of the developed models without intercept for 7 intermediary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.561*Students | 0.81 | 1592 |
| Attracted vehicles = 5.85*Employees | 0.80 | 2205 |
| Attracted vehicles = 14.895*Classes | 0.76 | 5607 |
| Attracted vehicles = 56.439*Floor area | 0.82 | 1163 |
| Attracted vehicles = 19.757*Lot area | 0.77 | 4831 |
| Attracted vehicles = 0.164*Distance to nearest school | 0.60 | 16830 |
| Attracted vehicles = 0.54*Distance to nearest arterial | 0.64 | 13833 |
| Attracted vehicles = 1.31*Distance to nearest collector | 0.50 | 24320 |
| Attracted vehicles = 0.053*Distance to CBD | 0.45 | 27658 |
| Attracted vehicles = 13.049*Classes+14.84*Lot area-6.98* Employees+36.94*Floor area | 0.66 | 296 |

**Table 2.11: Summary of the developed models with intercept for 10 intermediary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.7114*Students-65.292 | 0.87 | 923 |
| Attracted vehicles = 6.73*Employees-34.34 | 0.75 | 1778 |
| Attracted vehicles = 11.787*Classes+57.562 | 0.33 | 4670 |
| Attracted vehicles = 49.339*Floor area+33.462 | 0.80 | 1413 |
| Attracted vehicles = 13.226*Lot area+83.289 | 0.65 | 2474 |
| Attracted vehicles = 0.028*Distance to nearest school+189.85 | -0.09 | 7650 |
| Attracted vehicles = 0.044*Distance to nearest arterial+199.43 | -0.10 | 7677 |
| Attracted vehicles = -0.1462*Distance to nearest collector+200.71 | -0.06 | 7438 |
| Attracted vehicles = -0.0028*Distance to CBD+211.69 | -0.11 | 7812 |

**Table 2.12: Summary of the developed models without intercept for 10 intermediary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.5597*Students | 0.87 | 1120 |
| Attracted vehicles = 5.8891*Employees | 0.86 | 1671 |
| Attracted vehicles = 15.57*Classes | 0.82 | 4473 |
| Attracted vehicles = 57*Floor area | 0.87 | 1415 |
| Attracted vehicles = 19.72*Lot area | 0.83 | 3624 |
| Attracted vehicles = 0.17*Distance to nearest school | 0.68 | 13066 |
| Attracted vehicles = 0.34*Distance to nearest arterial | 0.60 | 17985 |
| Attracted vehicles = 0.920*Distance to nearest collector | 0.45 | 26867 |
| Attracted vehicles = 0.041*Distance to CBD | 0.48 | 25343 |

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of ten schools without intercept were used as the final results to make it easy to compare with the international models which use ratios in most situations.

### *2.1.3.2 Models Validation*

The remaining three schools which were not included in developing the models of seven schools without intercept were used to validate these models. Table 2.13 includes the observed values of dependent variable in the first column and the predicted values by the developed models of seven schools without intercept in the other columns.

**Table 2.13: Predicted values by different variables using the developed models (Intermediary, Trip Attraction)**

| **Number of attracted vehicles to school** | Students (difference) | Employees (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) | Classes + Lot Area + Employees + Floor Area (difference) |
|---|---|---|---|---|---|---|
| Coefficient | 0.56 | 5.85 | 14.90 | 56.4 | 19.76 | 13,14.84,6.98,36.94 |
| 160 | 157(-1%) | 123(-23%) | 104(-35%) | 102(-36%) | 104(-35%) | 89(-44%) |
| 199 | 218(10%) | 217(+9%) | 149(-25%) | 231(+16%) | 219(+10%) | 188(-6%) |
| 223 | 210(-6%) | 211(-5%) | 179(-20%) | 186(-17%) | 232(4%) | 202(-9%) |
| **Average difference %** | 6 | 12 | 27 | 23 | 16 | 19 |
| **Range %** | 1-10 | 5-23 | 20-35 | 16-36 | 4-35 | 6-44 |

*CV: coefficient of variation = Standard deviation / Mean*

$$Difference = \frac{\text{Predicted value} - \text{Observed value}}{\text{Observed value}} * 100\%$$

### *2.1.3.3 Discussion*

By comparing the models which resulted from the seven schools analysis with those that resulted from the ten schools analysis, it can be concluded that the study models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of the ten schools analysis. On the other hand, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of attracted vehicular trips to school when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which measures the average of the squares of the "errors" [28]. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

The result of multiple regression analysis is a simple regression model. Because of that, the best models are simple models.

Based on Table 2.12 which summarized the results of analysis of ten schools without intercept and Table 2.13 which contains the predicted numbers of attracted vehicles using the developed models, the best regression model with the lowest mean square residual that explains the attraction behavior to secondary schools is as follows:

**Model A: number of attracted vehicles = 0.56 * Number of students**

The model has the smallest mean square residual. The assumptions of normality, independency and equal variance of the model were checked graphically by considering the plot of residuals against the number of classes, the plot of residuals against the total lot area, the plot of residuals against the number of employees, the plot of residuals against the total floor area, and the normality plot of residuals. All assumptions seemed to be reasonable as shown in appendix A.

The other models which are significant in predicting the number of attracted trips to intermediary schools were arranged in order (from the smallest mean square error to the largest one) as follows:

**Model B: number of attracted vehicles = 57 * Total Floor Area**

**Model C: number of attracted vehicles = 5.89 * Number of Employees**

**Model D: number of attracted vehicles = 19.72 * Total Lot Area**

**Model E: number of attracted vehicles = 15.57 * Classes**

The characteristics of these models are summarized in Table 2.14 as shown below.

**Table 2.14: Characteristics of the developed models (Intermediary, Trip Attraction)**

| Model number | Variable | Coefficient | P-Value | **Mean square residual** |
|---|---|---|---|---|
| A | Students | 0.56 | 3.9E-09 | 1120 |
| B | Floor Area | 57 | 1.11E-08 | 1415 |
| C | Employees | 5.89 | 2.36E-08 | 1671 |
| D | Lot Area | 19.72 | 7.78E-07 | 3624 |
| E | Classes | 15.57 | 2.02E-06 | 4473 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the number of students and the normality plot of residuals. All assumptions seemed to be reasonable as shown in appendix A.

It is obvious that the worst models are those models that depend on the accessibility factors such as distance to nearest school, nearest arterial, nearest collector, and distance to CBD, which means that the accessibility factors are not significant in determining the number of attracted vehicles to schools.

### 2.1.4 Data Analysis for Primary Schools

#### *2.1.4.1 Summary of Results*

The correlation between the dependent variable (total attracted vehicles) and independent variables for primary schools was introduced by the following matrix (Table 2.15).

**Table 2.15: Correlation matrix for the variables of primary schools (10 schools)**

| | *Total Attracted* | *Number of Students* | *Number of Class-rooms* | *Number of Employees* | *Lot area (per 1000 sqm)* | *Floor area (per 1000 sqm)* | *Parking space* | *Dist to nearest school m* | *Dist to arterial m* | *Dist to collector m* | *Dist to CBD m* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Attracted | 1.00 | | | | | | | | | | |
| Students | 0.85 | 1.00 | | | | | | | | | |
| Classrooms | 0.86 | 0.97 | 1.00 | | | | | | | | |
| Employees | 0.88 | 0.92 | 0.97 | 1.00 | | | | | | | |
| Plot area | 0.78 | 0.42 | 0.52 | 0.63 | 1.00 | | | | | | |
| Floor area | 0.87 | 0.78 | 0.83 | 0.86 | 0.80 | 1.00 | | | | | |
| Parking space area | 0.66 | 0.48 | 0.49 | 0.64 | 0.74 | 0.67 | 1.00 | | | | |
| Dist to nearest school | -0.46 | -0.57 | -0.56 | -0.56 | -0.26 | -0.62 | -0.45 | 1.00 | | | |
| Dist to highway | 0.36 | 0.04 | 0.08 | 0.17 | 0.47 | 0.38 | 0.41 | -0.05 | 1.00 | | |
| Dist to collector | -0.02 | -0.16 | -0.17 | -0.16 | -0.02 | -0.11 | -0.06 | 0.58 | 0.65 | 1.00 | |
| Dist to CBD | 0.14 | -0.11 | -0.05 | -0.01 | 0.33 | 0.01 | 0.03 | 0.70 | 0.50 | 0.74 | 1.00 |

From the correlation matrix, it is clear that the most significant variables which have a strong linear relationship with the dependent variable are the number of students, classrooms, employees, lot area and floor area.

The relationships between the dependent variable y (total attracted vehicles) and independent variables for primary schools are summarized in Tables 2.16 to 2.19 as shown below.

**Table 2.16: Summary of the developed models with intercept for 7 primary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.3695*Students+41.654 | 0.68 | 1811 |
| Attracted vehicles = 4.6515*Employees+24.866 | 0.70 | 1679 |
| Attracted vehicles = 9.0665*Classes+31.241 | 0.70 | 1733 |
| Attracted vehicles = 46.274*Floor area+57.136 | 0.70 | 1681 |
| Attracted vehicles = 9.2706*Lot area+107.12 | 0.54 | 2621 |
| Attracted vehicles = -0.038*Distance to nearest school+219.30 | 0.18 | 4678 |
| Attracted vehicles = 0. 16*Distance to nearest arterial+122.63 | 0.004 | 5656 |
| Attracted vehicles = 0.51*Distance to nearest collector+177.31 | 0.25 | 7212 |
| Attracted vehicles = -0.0001*Distance to CBD+174.11 | -0.20 | 6820 |
| Attracted vehicles = 33.7+0.272*Students+5.92*Lot area | 0.90 | 550 |

**Table 2.17: Summary of the developed models without intercept for 7 primary schools (Trip Attraction)**

| **Model** | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|
| Attracted vehicles = 0.4662*Students | 0.0.79 | 1854 |
| Attracted vehicles = 5.3181*Employees | 0.80 | 1502 |
| Attracted vehicles = 10.753*Classes | 0.79 | 1617 |
| Attracted vehicles = 64.131*Floor area | 0.78 | 2211 |
| Attracted vehicles = 18.166*Lot area | 0.65 | 7585 |
| Attracted vehicles = 0.067*Distance to nearest school | 0.16 | 27688 |
| Attracted vehicles = 0.464*Distance to nearest arterial | 0.61 | 8951 |
| Attracted vehicles = 0.31*Distance to nearest collector | 0.044 | 32244 |
| Attracted vehicles = 0.028*Distance to CBD | 0.38 | 18693 |
| Attracted vehicles = 0.346*Students+6.20*Lot area | 0.78 | 708 |

**Table 2.18: Summary of the developed models with intercept for 10 primary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.3607*Students+43.64 | 0.69 | 1407 |
| Attracted vehicles = 4.7976*Employees+21.534 | 0.74 | 1141 |
| Attracted vehicles = 8.6752*Classes+38.969 | 0.70 | 1324 |
| Attracted vehicles = 44.362*Floor area+54.562 | 0.72 | 1240 |
| Attracted vehicles = 9.5437*Lot area+105.56 | 0.56 | 1976 |
| Attracted vehicles = -0.032*Distance to nearest school+203.25 | 0.11 | 3966 |
| Attracted vehicles = 0.066*Distance to nearest arterial+145.75 | 0.02 | 4364 |
| Attracted vehicles = -0.005*Distance to nearest collector+172.84 | -0.12 | 5028 |
| Attracted vehicles = 0.003*Distance to CBD+ 160.22 | -0.10 | 4927 |
| Attracted vehicles = 32.59+0.269*Students+6.29*Lot area | 0.92 | 359 |

**Table 2.19: Summary of the developed models without intercept for 10 primary schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.4652*Students | 0.85 | 1568 |
| Attracted vehicles = 5.402*Employees | 0.86 | 1077 |
| Attracted vehicles = 10.855*Classes | 0.85 | 1420 |
| Attracted vehicles = 61.285*Floor area | 0.84 | 1701 |
| Attracted vehicles = 19.315*Lot area | 0.72 | 6194 |
| Attracted vehicles = 0.078*Distance to nearest school | 0.23 | 24701 |
| Attracted vehicles = 0.27*Distance to nearest arterial | 0.50 | 14314 |
| Attracted vehicles = 0.31*Distance to nearest collector | 0.21 | 25347 |
| Attracted vehicles = 0.031*Distance to CBD | 0.48 | 15372 |
| Attracted vehicles = 0.34*Students+6.67*lot Area | 0.86 | 509 |

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of ten schools without intercept were used as the final results to make it easy to compare with the international models which use ratios in most situations.

### *2.1.4.2 Models Validation*

The remaining three schools which were not included in developing the models of seven schools without intercept were used to validate these models. Table 2.20 includes the observed values of dependent variable in the first column and the predicted values by the developed models of seven schools without intercept in the other columns.

**Table 2.20: Predicted values by different variables using the developed models (Primary, Trip Attraction)**

| **Number of attracted vehicles to school** | Students (difference) | Employees (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) | Students + Lot Area (difference) |
|---|---|---|---|---|---|---|
| Coefficient | 0.47 | 5.32 | 10.75 | 64.13 | 18.17 | 0.35,6.20 |
| 165 | 205(+24%) | 170(+3%) | 194(+18%) | 201(+22%) | 142(-14%) | 176(+6.5%) |
| 113 | 88(-22%) | 106(+6%) | 75(-34%) | 102(-10%) | 154(+36) | 97(-14%) |
| 223 | 196(-12%) | 197(-12%) | 194(-13%) | 259(+16%) | 201(-10%) | 208(-7%) |
| **Average difference %** | 19 | 7 | 22 | 16 | 20 | 9 |
| **Range%** | 12-24 | 3-12 | 13-34 | 10-22 | 10-36 | 6-14 |

*CV: coefficient of variation = Standard deviation / Mean*

$$\textit{Difference} = \frac{\text{Predicted value} - \text{Observed value}}{\text{Observed value}} * 100\%$$

### *2.1.4.3 Discussion*

By comparing the models which resulted from the seven schools analysis with those that resulted from the ten schools analysis, it can be concluded that the study models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of the ten schools analysis. On the other hand, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of attracted vehicular trips to school when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which measures the average of the squares of the "errors" [28]. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

Based on Table 2.19 which summarized the results of analysis of ten schools without intercept and Table 2.20 which contains the predicted numbers of attracted vehicles using the developed models, the best multiple and simple regression models with the lowest mean square residual that explains the attraction behavior to secondary schools are as follows:

**Model A: number of attracted vehicles = 0.34*Students+6.67*Lot Area**

**Model B: number of attracted vehicles = 5.40 * Number of Employees**

The models have the smallest mean square residual. The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the number of students, the plot of residuals against the total lot area, and the normality plot of residuals. All assumptions seemed to be reasonable.

The other models which are significant in predicting the number of attracted trips to primary schools were arranged in order (from the smallest mean square residual to the largest one) as follows:

**Model C: number of attracted vehicles = 10.86 * Number of Classes**

**Model D: number of attracted vehicles = 0.465 * Number of Students**

**Model E: number of attracted vehicles = 61.29 * Total Floor Area**

**Model F: number of attracted vehicles =19.315 * Total Lot Area**

The characteristics of these models are summarized in Table 2.21 as shown below.

**Table 2.21: Characteristics of the developed models (Primary, Trip Attraction)**

| Model number | Variable | Coefficient | P-Value | **Mean square residual** |
|---|---|---|---|---|
| A | Students<br>Lot Area | 0.34<br>6.67 | 8.06E-06<br>2.0E-03 | 509 |
| B | Employees | 5.40 | 3.12E-08 | 1077 |
| C | Classes | 10.86 | 1.09E-07 | 1420 |
| D | Students | 0.465 | 1.70E-07 | 1568 |
| E | Floor Area | 61.29 | 2.46E-07 | 1701 |
| F | Lot Area | 19.32 | 8.70E-05 | 6192 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the independent variables and the normality plot of residuals. All assumptions seemed to be reasonable.

It is obvious that the worst models are those models that depend on the accessibility factors such as distance to nearest school, nearest arterial, nearest collector, and distance to CBD, which means that the accessibility factors are not significant in determining the number of attracted vehicles to schools.

### 2.1.5 Data Analysis for All Levels Schools

#### *2.1.5.1 Summary of Results*

The simple regression analysis for all levels schools was done in the same procedure as each level of schools. The only difference is in multiple regression analysis which was done two times. The first time was done without distinguishing between the levels of schools. In the second multiple regression analysis, two dummy variables were used to distinguish between the levels of schools as follows:

Dummy 1 = 1 if secondary school, 0 otherwise

Dummy 2 = 1 if intermediary school, 0 otherwise

The correlation between the dependent variable (total attracted vehicles) and independent variables for all levels of schools was introduced by the following matrix (Table 2.22).

**Table 2.22: Correlation matrix for the variables of all levels of schools (30 schools)**

| | *Total Attracted* | *Number of Students* | *Number of Class-rooms* | *Number of Employees* | *Lot area (per 1000 sqm)* | *Floor area (per 1000 sqm)* | *Parking space* | *Dist to nearest school ml* | *Dist to highway m* | *Dist to collector m* | *Dist to CBD m* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Attracted | 1.00 | | | | | | | | | | |
| Students | 0.80 | 1.00 | | | | | | | | | |
| Classrooms | 0.66 | 0.82 | 1.00 | | | | | | | | |
| Employees | 0.84 | 0.81 | 0.69 | 1.00 | | | | | | | |
| Lot area | 0.72 | 0.51 | 0.31 | 0.70 | 1.00 | | | | | | |
| Floor area | 0.71 | 0.63 | 0.40 | 0.80 | 0.72 | 1.00 | | | | | |
| Parking space area | 0.53 | 0.47 | 0.30 | 0.62 | 0.70 | 0.60 | 1.00 | | | | |
| Dist to nearest school | -0.06 | -0.19 | -0.34 | -0.22 | -0.06 | 0.16 | 0.00 | 1.00 | | | |
| Dist to highway | 0.24 | 0.07 | -0.04 | 0.10 | 0.32 | 0.16 | 0.31 | 0.13 | 1.00 | | |
| Dist to collector | -0.05 | -0.26 | -0.30 | -0.27 | -0.07 | -0.09 | -0.06 | 0.55 | 0.48 | 1.00 | |
| Dist to CBD | 0.04 | -0.15 | -0.17 | -0.24 | 0.04 | -0.09 | 0.01 | 0.61 | 0.43 | 0.77 | 1.00 |

From the correlation matrix, it is clear that the most significant variables which have a strong linear relationship with the dependent variable are the number of students, employees, lot area and floor area.

The relationships between the dependent variable y (total attracted vehicles) and independent variables for intermediary schools are summarized in Tables 2.23 to 2.26 as shown below.

**Table 2.23: Summary of the developed models with intercept for 21 pooled schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.3566*Students+51.076 | 0.63 | 2464 |
| Attracted vehicles = 5.4388*Employees-6.2025 | 0.69 | 2073 |
| Attracted vehicles = 10.33*Classes+43.399 | 0.49 | 3400 |
| Attracted vehicles = 28.714*Floor area+85.338 | 0.46 | 3620 |
| Attracted vehicles = 10.262*Lot area+98.791 | 0.49 | 3454 |
| Attracted vehicles = -0.012*Distance to nearest school+218.57 | -0.02 | 6880 |
| Attracted vehicles = 0.075*Distance to nearest arterial+176.8 | -0.0017 | 6735 |
| Attracted vehicles = -0.077*Distance to nearest collector+212.5 | -0.026 | 6900 |
| Attracted vehicles = -0.0009*Distance to CBD+199.47 | -0.05 | 7071 |
| Attracted vehicles = -2.05+8.06*Classes+7.96*Lot area | 0.78 | 1472 |
| Attracted vehicles = 21.87+0.237*Students +16.08*Floor area -74.53*Dummy1+3.9*Lot area | 0.88 | 757 |

**Table 2.24: Summary of the developed models without intercept for 21 pooled schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.458*Students | 0.89 | 2763 |
| Attracted vehicles = 5.292*Employees | 0.91 | 1973 |
| Attracted vehicles = 12.823*Classes | 0.88 | 3460 |
| Attracted vehicles = 45.766*Floor area | 0.85 | 4863 |
| Attracted vehicles = 17.761*Lot area | 0.84 | 5683 |
| Attracted vehicles = 0.0867*Distance to nearest school | 0.41 | 26735 |
| Attracted vehicles = 0.41*Distance to nearest arterial | 0.61 | 16997 |
| Attracted vehicles = 0.552*Distance to nearest collector | 0.24 | 35333 |
| Attracted vehicles = 0.037*Distance to CBD | 0.45 | 24830 |
| Attracted vehicles = 7.97*Classes+7.92*Lot area | 0.92 | 1395 |
| Attracted vehicles = 0.264*Students +17.52*Floor area-76.52*Dummy1+4.10*Lot area | 0.93 | 794 |

**Table 2.25: Summary of the developed models with intercept for 30 pooled schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.3487*Students+55.817 | 0.62 | 1976 |
| Attracted vehicles = 5.4388*Employees-6.2025 | 0.70 | 1575 |
| Attracted vehicles = 8.6586*Classes+73.326 | 0.42 | 3026 |
| Attracted vehicles = 28.088*Floor area+86.737 | 0.48 | 2697 |
| Attracted vehicles = 10.188*Lot area+101.12 | 0.51 | 2578 |
| Attracted vehicles = -0.0039*Distance to nearest school+201.69 | -0.03 | 5374 |
| Attracted vehicles = 0.051*Distance to nearest arterial+173.87 | 0.02 | 5081 |
| Attracted vehicles = -0.019*Distance to nearest collector+199.74 | -0.03 | 5382 |
| Attracted vehicles = 0.0012*Distance to CBD+ 192.67 | -0.03 | 5386 |
| Attracted vehicles = 37.65+0.253*Students+6.05*Lot area | 0.75 | 1289 |
| Attracted vehicles = 30.85+0.21*Students +18.23*Floor area -59.39*Dummy1+3.13*Lot area | 0.85 | 801 |

**Table 2.26: Summary of the developed models without intercept for 30 pooled schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.4678*Students | 0.91 | 2355 |
| Attracted vehicles = 5.2923*Employees | 0.93 | 1526 |
| Attracted vehicles = 13.155*Classes | 0.89 | 3629 |
| Attracted vehicles = 46.437*Floor area | 0.88 | 3949 |
| Attracted vehicles = 18.564*Lot area | 0.86 | 4860 |
| Attracted vehicles = 0.082*Distance to nearest school | 0.44 | 23724 |
| Attracted vehicles = 0.30*Distance to nearest arterial | 0.61 | 16281 |
| Attracted vehicles = 0.49*Distance to nearest collector | 0.32 | 28936 |
| Attracted vehicles = 0.035*Distance to CBD | 0.52 | 20255 |
| Attracted vehicles = 0.316*Students+6.83*Lot area | 0.93 | 1435 |
| Attracted vehicles = 0.252*Students +20.51*Floor Area-61.79*Dummy1+3.34*Lot area | 0.94 | 908 |

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of 30 schools without intercept were used as the final results to make it easy to compare with the international models which use ratios in most situations.

#### *2.1.5.2 Models Validation*

The remaining nine schools which were not included in developing the models were used to validate these models. Table 2.27 includes the observed values of dependent variable in the first column and the predicted values by all the developed models in the other columns.

**Table 2.27: Predicted values by different variables using the developed models (All Levels, Trip Attraction)**

| **Number of attracted vehicles to school** | Employees (difference) | Students (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) | Classes + Lot Area (difference) | Students + Dummy1 + Lot Area + Floor Area (difference) |
|---|---|---|---|---|---|---|---|
| Coefficients | 5.292 | 0.49 | 12.82 | 45.77 | 17.76 | 7.97,7.92 | 0.264,17.52,-76.52,4.1 |
| 245 | 254(+3.5%) | 205(-16%) | 128(-47%) | 264(+7%) | 164(-33%) | 153(-38%) | 181(-26%) |
| 172 | 159(-7.5%) | 115(-33%) | 115(-33%) | 220(+28%) | 94(-46%) | 113(-34%) | 95(-44%) |
| 149 | 169(+13.5) | 199(+33%) | 167(+12%) | 148(0%) | 135(-9%) | 164(+10%) | 121(-19%) |
| 160 | 111(-30.5%) | 128(-20%) | 90(-44%) | 82(-49%) | 94(-42%) | 97(-39%) | 127(-20.5%) |
| 199 | 196(-1.5%) | 178(-11%) | 128(-36%) | 188(-6%) | 197(-1%) | 168(-16%) | 220(+10%) |
| 223 | 191(-14.5%) | 172(-23%) | 154(-31%) | 151(-32%) | 209(-6%) | 189(-15%) | 205(-8%) |
| 165 | 169(+2.5%) | 202(+22%) | 231(+40%) | 144(-13%) | 67(-59%) | 173(+5%) | 186(+13%) |
| 113 | 106(-6%) | 86(-24%) | 90(-21%) | 73(+-36%) | 91(-20%) | 96(-15%) | 98(-13%) |
| 223 | 196(-12%) | 192(-14%) | 231(+3.5%) | 185(-17%) | 180(-19%) | 224(0%) | 223(0%) |
| **Average difference %** | **10** | **20** | **29** | **21** | 26 | 19 | 17 |
| **Range** | **1.5-30.5** | **11-33** | **3.5-47** | **0-49** | 1-59 | 0-39 | 0-44 |

*CV: coefficient of variation = Standard deviation / Mean*

$$Difference = \frac{\text{Predicted value} - \text{Observed value}}{\text{Observed value}} * 100\%$$

#### *2.1.5.3 Discussion*

By comparing the models which resulted from the 21 schools analysis with those that resulted from the 30 schools analysis, it can be concluded that the study models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of 30 schools analysis. On the other hand, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of attracted vehicular trips to school when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which measures the average of the squares of the “errors”. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

Based on Table 2.26 which summarized the results of analysis of 30 schools without intercept and Table 2.27 which contains the predicted numbers of attracted vehicles using the developed models, the best multiple and simple regression models with the lowest mean square residual that explains the attraction behavior to secondary schools are as follows:

**Model A: number of attracted vehicles = 0.252 * Number of Students + 20.51 * Floor Area - 61.79 * Dummy + 3.34 * Lot Area**

Where, Dummy1 = 1 if secondary, 0 otherwise

**Model B: number of attracted vehicles = 5.29 * Number of Employees**

The models have the smallest mean square residual. The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the number of employees and the normality plot of residuals. All assumptions seemed to be reasonable.

The other models which are significant in predicting the number of attracted trips to schools were arranged in order (from the smallest mean square error to the largest one) as follows:

**Model C: number of attracted vehicles = 0.316*Students+6.83*Lot Area**

**Model D: number of attracted vehicles = 0.468 * Number of Students**

**Model E: number of attracted vehicles = 13.16 * Number of Classes**

**Model F: number of attracted vehicles = 46.44 * Total Floor Area**

**Model G: number of attracted vehicles = 18.56 * Total Lot Area**

The characteristics of these models are summarized in Table 2.28 as shown below.

**Table 2.28: Characteristics of the developed models (All Levels, Trip Attraction)**

| Model number | Variable | Coefficient | P-Value | **Mean square residual** |
|---|---|---|---|---|
| A | Students | 0.252 | 7.7E-07 | 908 |
| | Floor Area | 20.51 | 2.0E-03 | |
| | Lot Area | 3.34 | 5.0E-02 | |
| | Dummy1 | 61.79 | 3.0E-04 | |
| B | Employees | 5.29 | 6.89E-23 | 1526 |
| C | Students | 0.316 | 4.12E-09 | 1435 |
| | Lot Area | 6.83 | 1.0E-04 | |
| D | Students | 0.468 | 3.75E-20 | 2355 |
| E | Classes | 13.16 | 2.0E-17 | 3629 |
| F | Floor Area | 46.44 | 6.88E-17 | 3949 |
| G | Lot Area | 18.56 | 1.41E-15 | 4860 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the independent variables and the normality plot of residuals. All assumptions seemed to be reasonable.

It is obvious that the worst models are those models that depend on the accessibility factors, such as distance to nearest school, nearest arterial, nearest collector, and distance to CBD, which means that the accessibility factors are not significant in determining the number of attracted vehicles to schools.

From **“model A”**, it is clear that the secondary schools have the significant effect because of the appearance of the dummy variable which is related to secondary schools. Because of that, another trial of analysis in which the primary and intermediary schools were pooled together, was performed as shown in the next section.

### 2.1.6 Data Analysis for Primary & Intermediary Schools

#### *2.1.6.1 Summary of Results*

The correlation between the dependent variable (total attracted vehicles) and independent variables for primary and intermediary schools was introduced by the following matrix (Table 2.29).

**Table 2.29: Correlation matrix for the variables of primary & intermediary schools (20 schools)**

| | *Total Attracted vehicles* | *Number of Students* | *Number of Classes* | *Number of Employees* | *Lot area (per 1000 sqm)* | *Floor area (per 1000 sqm)* | *Parking space* | *Dist to nearest school m* | *Dist to highway m* | *Dist to collector m* | *Dist to CBD m* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Attracted | 1.00 | | | | | | | | | | |
| Students | 0.85 | 1.00 | | | | | | | | | |
| Classes | 0.64 | 0.85 | 1.00 | | | | | | | | |
| Employees | 0.88 | 0.91 | 0.76 | 1.00 | | | | | | | |
| Lot area | 0.82 | 0.57 | 0.34 | 0.76 | 1.00 | | | | | | |
| Floor area | 0.90 | 0.80 | 0.60 | 0.91 | 0.83 | 1.00 | | | | | |
| Parking space area | 0.56 | 0.51 | 0.31 | 0.68 | 0.76 | 0.65 | 1.00 | | | | |
| Dist to nearest school | -0.15 | -0.31 | -0.37 | -0.30 | -0.07 | -0.28 | -0.27 | 1.00 | | | |
| Dist to highway | 0.29 | 0.11 | -0.03 | 0.16 | 0.36 | 0.24 | 0.38 | -0.08 | 1.00 | | |
| Dist to collector | 0.02 | -0.10 | -0.17 | -0.16 | -0.01 | -0.12 | -0.07 | 0.50 | 0.54 | 1.00 | |
| Dist to CBD | 0.10 | -0.03 | -0.10 | -0.09 | 0.16 | -0.10 | -0.04 | 0.53 | 0.55 | 0.74 | 1.00 |

From the correlation matrix, it is clear that the most significant variables which have a strong linear relationship with the dependent variable are the number of students, employees, lot area and floor area.

The relationships between the dependent variable y (total attracted vehicles) and independent variables for primary and intermediary schools pooled together are summarized in Tables 2.30 to 2.33 as shown below.

**Table 2.30: Summary of the developed models with intercept for 14 schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.52*Students-0.086 | 0.72 | 2171 |
| Attracted vehicles = 6.09*Employees-18.28 | 0.70 | 1930 |
| Attracted vehicles = 10.69*Classes+57.40 | 0.40 | 4834 |
| Attracted vehicles = 48.27*Floor area+43.02 | 0.82 | 1464 |
| Attracted vehicles = 11.71*Lot area+97.56 | 0.64 | 2868 |
| Attracted vehicles = -0.02*Distance to nearest school+233.67 | 0.02 | 8208 |
| Attracted vehicles = 0.21*Distance to nearest arterial+132.17 | 0.14 | 6891 |
| Attracted vehicles = 0.03*Distance to nearest collector+207.65 | 0.08 | 8656 |
| Attracted vehicles = 0.002*Distance to CBD+196 | 0.08 | 8647 |
| Attracted vehicles = 4.40+0.35*Students+6.73*Lot area | 0.88 | 999 |

**Table 2.31: Summary of the developed models without intercept for 14 schools (Trip Attraction)**

| **Model** | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|
| Attracted vehicles = 0. 519*Students | 0.88 | 2004 |
| Attracted vehicles = 5.63*Employees | 0.89 | 1820 |
| Attracted vehicles = 12.71*Classes | 0.836 | 4604 |
| Attracted vehicles = 58.70*Floor area | 0.89 | 1738 |
| Attracted vehicles = 19.17*Lot area | 0.81 | 5805 |
| Attracted vehicles = 0.11*Distance to nearest school | 0.43 | 25852 |
| Attracted vehicles = 0.51*Distance to nearest arterial | 0.72 | 10742 |
| Attracted vehicles = 0.54*Distance to nearest collector | 0.23 | 36244 |
| Attracted vehicles = 0.037*Distance to CBD | 0.45 | 24384 |
| Attracted vehicles = 0.36*Students+6.73*Lot area | 0.90 | 918 |

**Table 2.32: Summary of the developed models with intercept for 20 schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.50*Students+8.83 | 0.72 | 1731 |
| Attracted vehicles = 5.80*Employees-4.56 | 0.76 | 1457 |
| Attracted vehicles = 8.92*Classes+66.36 | 0.37 | 3824 |
| Attracted vehicles = 46.51*Floor area+46.57 | 0.80 | 1199 |
| Attracted vehicles = 11.61*Lot area+95.67 | 0.66 | 2099 |
| Attracted vehicles = -0.016*Distance to nearest school+213.24 | -0.03 | 6274 |
| Attracted vehicles = 0.067*Distance to nearest arterial+166.50 | 0.03 | 5889 |
| Attracted vehicles = 0.005*Distance to nearest collector+195.57 | -0.05 | 6423 |
| Attracted vehicles = 0.003*Distance to CBD+ 186.36 | -0.04 | 6355 |
| Attracted vehicles = 10+0.33*Students+6.99*Lot area | 0.88 | 715 |

**Table 2.33: Summary of the developed models without intercept for 20 schools (Trip Attraction)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Attracted vehicles = 0.52*Students | 0.91 | 1649 |
| Attracted vehicles = 5.69*Employees | 0.92 | 1382 |
| Attracted vehicles = 12.91*Classes | 0.86 | 4185 |
| Attracted vehicles = 58.45*Floor area | 0.91 | 1530 |
| Attracted vehicles = 19.58*Lot area | 0.85 | 4655 |
| Attracted vehicles = 012*Distance to nearest school | 0.48 | 21607 |
| Attracted vehicles = 0.31*Distance to nearest arterial | 0.61 | 15736 |
| Attracted vehicles = 0.46*Distance to nearest collector | 0.30 | 30165 |
| Attracted vehicles = 0.036*Distance to CBD | 0.52 | 19833 |
| Attracted vehicles = 0.36*Students+6.98*Lot area | 0.93 | 688 |

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of ten schools without intercept were used as the final results to make it easy to compare with the international models which use ratios in most situations.

### *2.1.6.2 Models Validation*

The remaining six schools which were not included in developing the models of 14 schools without intercept were used to validate these models. Table 2.34 includes the observed values of dependent variable in the first column and the predicted values by the developed models of seven schools without intercept in the other columns.

**Table 2.34: Predicted values by the developed models (Primary & Intermediary, Trip Attraction)**

| **Observed values** | Students (difference) | Employees (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) | Students + Lot Area (difference) |
|---|---|---|---|---|---|---|
| Coefficient | 0.52 | 5.63 | 12.71 | 58.70 | 19.17 | 0.36,6.73 |
| 165 | 228(+38%) | 182(+10%) | 232(+41%) | 183(+11%) | 74(-55%) | 184(+12%) |
| 113 | 98(-12%) | 114(0%) | 90(-20%) | 93(-18%) | 100(-11%) | 102(-10%) |
| 223 | 218(-2%) | 211(-5%) | 232(+4%) | 236(+6%) | 199(-11%) | 219(-2%) |
| 160 | 146(-9%) | 120(-25%) | 90(-44%) | 105(-34%) | 103(-36%) | 136(-15%) |
| 199 | 202(+1%) | 211(+6%) | 129(-35%) | 239(+20%) | 217(+10%) | 215(+8%) |
| 223 | 195(-12%) | 205(-8%) | 155(-30%) | 193(-13%) | 230(+3%) | 214(-4%) |
| **Average difference %** | 12 | 9 | 29 | 17 | 21 | 8.5 |
| **Range%** | 1-38 | 0-10 | 4-44 | 6-34 | 3-55 | 2-15 |

*CV: coefficient of variation = Standard deviation / Mean*

$$\textit{Difference} = \frac{\text{Predicted value} - \text{Observed value}}{\text{Observed value}} * 100\%$$

#### *2.1.6.3 Discussion*

By comparing the models which resulted from the 14 schools analysis with those that resulted from the 20 schools analysis, it can be concluded that the study models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of 20 schools analysis. On the other hand, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of attracted vehicular trips to school when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which measures the average of the squares of the "errors" [28]. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

Based on Table 2.33 which summarized the results of analysis of ten schools without intercept and Table 2.34 which contains the predicted numbers of attracted vehicles using the developed models, the best multiple and simple regression models with the lowest mean square residual that explains the attraction behavior to secondary schools are as follows:

**Model A: number of attracted vehicles = 0.36 * Students + 6.98 * Lot Area**

**Model B: number of attracted vehicles = 5.69 * Number of Employees**

The models have the smallest mean square residual. The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the number of students, the plot of residuals against the total lot area, and the normality plot of residuals. All assumptions seemed to be reasonable.

The other models which are significant in predicting the number of attracted trips to primary and intermediary schools were arranged in order (from the smallest mean square error to the largest one) as follows:

**Model C: number of attracted vehicles = 58.48 * Total Floor Area**

**Model D: number of attracted vehicles = 0.52 * Number of Students**

**Model E: number of attracted vehicles = 12.91 * Number of Classes**

**Model F: number of attracted vehicles = 19.58 * Total Lot Area**

The characteristics of these models are summarized in Table 2.35 as shown below.

**Table 2.35: Characteristics of the developed models (Primary & Intermediary, Trip Attraction)**

| Model number | Variable | Coefficient | P-Value | **Mean square residual** |
|---|---|---|---|---|
| A | Students<br>Lot area | 0.36<br>6.98 | 4.11E-09<br>5.45E-05 | 688 |
| B | Employees | 5.69 | 5.45E-16 | 1382 |
| C | Floor area | 58.48 | 1.43E-15 | 1530 |
| D | Students | 0.52 | 2.920E-15 | 1649 |
| E | Classes | 12.91 | 2.08E-11 | 4185 |
| F | Lot area | 19.58 | 5.750E-11 | 4655 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the independent variables and the normality plot of residuals. All assumptions seemed to be reasonable.

It is obvious that the worst models are those models that depend on the accessibility factors, such as distance to nearest school, nearest arterial, nearest collector, and distance to CBD, which means that the accessibility factors are not significant in determining the number of attracted vehicles to schools.

## 2.2 Comparison between Local & International Models

The comparison was done between the trip generation manual of Riyadh city which presents the only option for local models and the international models such as the Institute of Transportation Engineers (ITE) trip generation manual and Dubai trip generation and parking rates manual. Tables 2.36 to 2.44 present the predicted values by all of these models for different variables for each level of schools.

### 2.2.1 Secondary Schools

**Table 2.36: Predicted values by ITE rates for secondary schools (Trip Attraction)**

| **Number of attracted vehicles** | Students (difference) | Employees (difference) | 1000 sq m Gross Floor Area (difference) |
|---|---|---|---|
| 290 | 363(+25%) | 239(-18%) | 178(-39%) |
| 240 | 303(+26%) | 211(-12%) | 188(-22%) |
| 250 | 226(-10%) | 257(+3%) | 277(+11%) |
| 157 | 130(-17%) | 112(-28%) | 192(+22.5) |
| 235 | 210(-10%) | 248(+6%) | 224(-5%) |
| 121 | 123(+2%) | 173(+43%) | 106(-12%) |
| 107 | 80(-25%) | 140(+31%) | 120(+12) |
| 245 | 188(-23%) | 224(-8%) | 190(-22%) |
| 172 | 105(-39%) | 140(-18%) | 158(-8%) |
| 149 | 174(+17%) | 149(0%) | 106(-28.5%) |
| **Average difference %** | **19.4** | **16.7** | **18.2** |
| **Range of difference** | **2-39** | **0-43** | **5-39** |

**Table 2.37: Predicted values by Riyadh city manual for secondary schools (Trip Attraction)**

| **Number of attracted vehicles** | Students (difference) | Lot Area (difference) |
|---|---|---|
| 290 | 565(+95%) | 1202(+314%) |
| 240 | 471(+96%) | 1653(+589%) |
| 250 | 351(+40%) | 1334(+434%) |
| 157 | 203(+29%) | 1543(+883%) |
| 235 | 327(+39%) | 2246(+855%) |
| 121 | 191(+58%) | 1160(+859%) |
| 107 | 125(+17%) | 746(+597%) |
| 245 | 293(+20%) | 1073(+380%) |
| 172 | 172(-4.5%) | 611(+255%) |
| 149 | 271(+82%) | 882(+492%) |
| **Average difference %** | **48** | **566** |
| **Range of difference** | **4.5-96** | **255-883** |

**Table 2.38: Predicted values by Dubai trip generation manual for secondary schools (Trip Attraction)**

| **Number of attracted vehicles** | Students (difference) |
|---|---|
| 290 | 449(+55%) |
| 240 | 374(+56%) |
| 250 | 279(+11%) |
| 157 | 161(+2.5%) |
| 235 | 260(+10.5%) |
| 121 | 152(+26%) |
| 107 | 99(-7%) |
| 245 | 233(-5%) |
| 172 | 131(-24%) |
| 149 | 215(+44%) |
| **Average difference %** | **24** |
| **Range of difference** | **5-56** |

### 2.2.2 Intermediary Schools

**Table 2.39: Predicted values by ITE rates for intermediary schools (Trip Attraction)**

| **Number of Attracted vehicles** | Students (difference) | Employees (difference) | 1000 sq m Gross Floor Area (difference) |
|---|---|---|---|
| 333 | 276(-17%) | 276(-17%) | 266(-20%) |
| 321 | 319(-1%) | 254(-21%) | 229(-28.5%) |
| 261 | 228(-13%) | 244(-7%) | 250(-4%) |
| 270 | 254(-6%) | 212(-21%) | 208(-23%) |
| 240 | 225(-6%) | 223(-7%) | 197(-18%) |
| 150 | 202(+35%) | 212(+41%) | 167(+12%) |
| 57 | 108(+89) | 95(+67%) | 36(-37%) |
| 160 | 151(-5.5%) | 111(-30%) | 84(-47%) |
| 199 | 210(+5.5%) | 196(-1.5%) | 192(-3.5%) |
| 223 | 202(-9%) | 191(-14%) | 155(-31%) |
| **Average difference %** | **19** | **23** | **22** |
| **Range of difference** | **1-89** | **7-67** | **3.5-47** |
| **CV** | **0.26** | **0.27** | **0.38** |

**Table 2.40: Predicted values by Riyadh city manual for intermediary schools (Trip Attraction)**

| **Number of attracted vehicles** | Students (difference) | Gross Floor Area (difference) | Classes (difference) |
|---|---|---|---|
| 333 | 384(+15%) | 1306(+293%) | 345(+4%) |
| 321 | 443(+39%) | 1127(+251%) | 415(+29%) |
| 261 | 317(+21%) | 1226(+370%) | 345(+32%) |
| 270 | 353(+31%) | 1021(+278%) | 530(+96%) |
| 240 | 313(+30%) | 966(+303%) | 345(+44%) |
| 150 | 281(+88%) | 822(+448%) | 322(+114%) |
| 57 | 150(+160%) | 176(+209%) | 230(+304%) |
| 160 | 210(+31%) | 414(+159%) | 161(0%) |
| 199 | 292(+47%) | 943(+374%) | 230(+16%) |
| 223 | 281(+26%) | 759(+240%) | 276(+24%) |
| **Average difference %** | **49** | **293** | **66** |
| **Range of difference** | **15-160** | **159-448** | **0-114** |

**Table 2.41: Predicted values by Dubai trip generation manual for intermediary schools (Trip Attraction)**

| **Number of attracted vehicles** | Students (difference) |
| --- | --- |
| 333 | 220(-34%) |
| 321 | 254(-21%) |
| 261 | 181(-30%) |
| 270 | 202(-25%) |
| 240 | 179(-25%) |
| 150 | 161(+7.5%) |
| 57 | 86(+51%) |
| 160 | 120(-25%) |
| 199 | 167(-16%) |
| 223 | 161(-28%) |
| **Average difference %** | 26 |
| **Range of difference** | **7.5-51** |

### 2.2.3 Primary Schools

**Table 2.42: Predicted values by ITE rates for primary schools (Trip Attraction)**

| **Number of attracted vehicles** | Students (difference) | Employees (difference) | 1000 sq m Gross Floor Area (difference) |
|---|---|---|---|
| 260 | 185(-29%) | 231(-11%) | 234(-10%) |
| 170 | 194(+14%) | 242(+42%) | 185(+8.5%) |
| 220 | 169(-23%) | 166(-24%) | 176(-21%) |
| 156 | 140(-10%) | 150(-3.5%) | 89(-43%) |
| 250 | 296(+18%) | 258(+3%) | 205(-18%) |
| 100 | 91(-9%) | 91(-9%) | 16(-84%) |
| 60 | 51(-14%) | 64(+7%) | 83(+39%) |
| 165 | 198(+20%) | 171(+4%) | 176(+6%) |
| 113 | 85(-25%) | 107(-5%) | 89(-21%) |
| 223 | 189(15%) | 199(-11%) | 226(+1.5%) |
| **Average difference %** | **18** | **12** | **25** |
| **Range of difference** | **9-29** | **3-42** | **1.5-84** |

**Table 2.43: Predicted values by Riyadh city manual for primary schools (Trip Attraction)**

| **Number of attracted vehicles** | Students (difference) | Lot Area (difference) | Employees (difference) |
|---|---|---|---|
| 260 | 271(+4%) | 1859(+615%) | 428(+65%) |
| 170 | 284(+67%) | 823(+384%) | 448(+164%) |
| 220 | 248(+12.5%) | 1166(+430%) | 309(+40%) |
| 156 | 205(+32%) | 230(+47%) | 279(+79%) |
| 250 | 434(+74%) | 664(+165%) | 478(+91%) |
| 100 | 134(+34%) | 28(-72%) | 169(+69%) |
| 60 | 76(+26.5%) | 258(+330%) | 120(+99%) |
| 165 | 290(+76%) | 377(+128%) | 319(+93%) |
| 113 | 124(+10%) | 511(+352%) | 199(+76%) |
| 223 | 277(+24%) | 1014(+355%) | 369(+65%) |
| **Average difference %** | **36** | **288** | **84** |
| **Range of difference** | **4-74** | **47-615** | **40-164** |

**Table 2.44: Predicted values by Dubai trip generation manual for primary schools (Trip Attraction)**

| **Number of attracted vehicles** | Students (difference) |
|---|---|
| 260 | 176(-32%) |
| 170 | 185(+9%) |
| 220 | 161(-27%) |
| 156 | 134(-14%) |
| 250 | 283(+13%) |
| 100 | 87(-13%) |
| 60 | 49(-18%) |
| 165 | 189(+15%) |
| 113 | 81(-28%) |
| 223 | 181(-19%) |
| **Average difference %** | 19 |
| **Range of difference** | **9-32** |

## 2.3 Summary of Results

Tables 2.45 to 2.49 present the best models developed by the study for each type of analysis.

**Table 2.45: Summary of the developed models for secondary schools (Trip Attraction)**

| Model number | Developed models | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|---|
| A | Attracted vehicles = 0.208*Students+19.12 Floor area | 0.89 | 473 |
| B | Attracted vehicles = 4.84*Employees | 0.86 | 1166 |
| C | Attracted vehicles = 36.47*Floor area | 0.84 | 2112 |
| D | Attracted vehicles = 0.40*Students | 0.84 | 2188 |
| E | Attracted vehicles = 13.72*Classes | 0.83 | 5210 |
| F | Attracted vehicles = 16.94*Lot area | 0.77 | 2752 |

**Table 2.46: Summary of the developed models for intermediary schools (Trip Attraction)**

| Model number | Developed models | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|---|
| A | Attracted vehicles = 0.56*Students | 0.87 | 1120 |
| B | Attracted vehicles = 57*Floor Area | 0.87 | 1415 |
| C | Attracted vehicles = 5.89*Employees | 0.86 | 1671 |
| D | Attracted vehicles = 19.72*Lot area | 0.83 | 3624 |
| E | Attracted vehicles = 15.57*Classes | 0.82 | 4473 |

**Table 2.47: Summary of the developed models for primary schools (trip attraction)**

| Model number | Developed model | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|---|
| A | Attracted vehicles = 0.34*Students+ 6.67*Lot area | 0.86 | 509 |
| B | Attracted vehicles = 5.4*Employees | 0.86 | 1077 |
| C | Attracted vehicles = 10.86*Classes | 0.85 | 1420 |
| D | Attracted vehicles = 0.465*Students | 0.85 | 1568 |
| E | Attracted vehicles = 61.29*Floor Area | 0.84 | 1701 |
| F | Attracted vehicles = 19.32*Lot area | 0.72 | 6192 |

**Table 2.48: Summary of the developed models for all levels of schools (Trip Attraction)**

| Model number | Developed model | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|---|
| A | Attracted vehicles = 0.252*Students +20.51*Floor area+3.34*Lot area-61.79*Dummy | 0.94 | 908 |
| B | Attracted vehicles = 5.29*Employees | 0.93 | 1526 |
| C | Attracted vehicles = 0.316*Students+ 6.83*Lot area | 0.93 | 1435 |
| D | Attracted vehicles = 0.468*Students | 0.91 | 2355 |
| E | Attracted vehicles = 13.16*Classes | 0.89 | 3629 |
| F | Attracted vehicles = 46.44*Floor area | 0.88 | 3949 |
| G | Attracted vehicles = 18.56*Lot area | 0.86 | 4860 |

**Table 2.49: Summary of the developed models for primary & intermediary of schools Ttrip Attraction)**

| Model number | Developed model | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|---|
| A | Attracted vehicles = 0.36*Students+ 6.98*Lot area | 0.93 | 688 |
| B | Attracted vehicles = 5.69*Employees | 0.92 | 1382 |
| C | Attracted vehicles = 58.48*Floor area | 0.91 | 1530 |
| D | Attracted vehicles = 0.52*Students | 0.91 | 1649 |
| E | Attracted vehicles = 12.91*Classes | 0.86 | 4185 |
| F | Attracted vehicles = 19.58*Lot area | 0.85 | 4655 |

By comparing the predicted values with the observed values for each level of schools, it is obvious that the worst models in predicting the number of attracted vehicles to schools are Riyadh city manual models since in most cases these models overestimated the number of attracted vehicles, especially when the variable used is the lot or floor area. The main reason for this overestimating is that the Riyadh city manual was prepared based on the data from schools of boys and girls. ITE and Dubai trip generation rates predicted the number of attracted vehicles much better than that predicted by Riyadh city rates. It is suggested to use the international models (ITE and Dubai trip generation rates) rather than the local models in the study area.

# CHAPTER 3

# MODELING OF PARKING GENERATION

## 3.1 Data Analysis and Discussion

Regression analysis is a statistical tool for the investigation of relationships between variables. Usually, the investigator seeks to ascertain the causal effect of one variable upon another.

In this study, single and multiple regressions were used to develop a model which predicts the parking demand for schools using many of the dependent variables

### 3.1.1 Experimental Design

A set of explanatory factors summarizing the characteristics of schools was evaluated. The relationship between these explanatory variables and the number of parked vehicles (dependent variable) was thoroughly investigated through regression. The explanatory variables are:

- The number of students
- The number of employees
- The number of classrooms
- Total floor area: the sum (in square meter) of the area of each floor level for all buildings.

- Total lot area: defined as the area (in square meter) of the built and unbuilt land owned by the school.
- Availability of parking space lots: was presented as a dummy variable in multiple regression analysis.

For each dependent variable, the analysis was done four times for each level of schools as described below:

1. Data analysis for seven schools with intercept
2. Data analysis for seven schools without intercept
3. Data analysis for ten schools with intercept
4. Data analysis for ten schools without intercept

The purpose of analyzing seven schools out of ten was to use the remaining three schools in the validation process, which can help in determining the best fit models. For each level of schools, the models which resulted from analyzing seven schools were compared with those that resulted from analyzing ten schools.

The same procedure was done when all schools were pooled together as described below:

1. Data analysis for 21 schools with intercept
2. Data analysis for 21 schools with intercept using two dummy variables to distinguish between the three levels of schools
3. Data analysis for 21 schools without intercept
4. Data analysis for 21 schools without intercept using two dummy variables to distinguish between the three levels of schools
5. Data analysis for 30 schools with intercept

6. Data analysis for 30 schools with intercept using two dummy variables to distinguish between the three levels of schools
7. Data analysis for 30 schools without intercept
8. Data analysis for 30 schools without intercept using two dummy variables to distinguish between the three levels of schools

The data were analyzed using the SPSS software.

### 3.1.2 Data Analysis for Secondary Schools

#### *3.1.2.1 Summary of Results*

The correlation between the dependent variable (parked vehicles) and independent variables for secondary schools was introduced by the following matrix (Table 3.1).

**Table 3.1: Correlation matrix for the variables of secondary schools (10 schools)**

| | *Parked* | *Total Attracted* | *Students* | *Classes* | *Employees* | *Lot area* | *Floor area* | *Parking space area* | *Dist to nearest school* | *Dist to arterial* | *Dist to collector* | *Dist to CBD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parked | 1.00 | | | | | | | | | | | |
| Total Attracted | 0.81 | 1.00 | | | | | | | | | | |
| Students | 0.63 | 0.87 | 1.00 | | | | | | | | | |
| Classes | 0.41 | 0.76 | 0.94 | 1.00 | | | | | | | | |
| Employees | 0.58 | 0.84 | 0.72 | 0.68 | 1.00 | | | | | | | |
| lot area | 0.31 | 0.44 | 0.42 | 0.36 | 0.50 | 1.00 | | | | | | |
| Floor area | 0.42 | 0.72 | 0.43 | 0.42 | 0.66 | 0.58 | 1.00 | | | | | |
| Parking space area | 0.52 | 0.50 | 0.43 | 0.47 | 0.33 | 0.36 | 0.35 | 1.00 | | | | |
| Dist to nearest school | 0.13 | 0.01 | -0.26 | -0.34 | -0.40 | -0.23 | 0.23 | 0.12 | 1.00 | | | |
| Dist to arterial | 0.04 | 0.14 | 0.02 | -0.08 | 0.02 | 0.24 | 0.11 | 0.21 | 0.34 | 1.00 | | |
| Dist to collector | -0.02 | -0.29 | -0.57 | -0.66 | -0.59 | -0.27 | 0.00 | 0.01 | 0.91 | 0.35 | 1.00 | |
| Dist to CBD | 0.12 | -0.12 | -0.30 | -0.34 | -0.57 | -0.26 | 0.04 | 0.25 | 0.92 | 0.20 | 0.89 | 1.00 |

From the correlation matrix, it is clear that the most significant variable which has a strong linear relationship with the dependent variable (parked vehicles) is the number of students.

The relationships between the dependent variable y (parked vehicles) and independent variables for secondary schools are summarized in Tables 3.2 to 3.5 as shown below.

**Table 3.2: Summary of the developed models with intercept for 7 secondary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.101*Students+28.69 | 0.51 | 506 |
| Parked vehicles = 1.61*Employees-9.82 | 0.24 | 774 |
| Parked vehicles = 3.06*Classes+32.79 | 0.25 | 768 |
| Parked vehicles = 7.87*Floor area+34.03 | 0.03 | 996 |
| Parked vehicles = 3.96*Lot area+29.62 | 0.10 | 919 |

**Table 3.3: Summary of the developed models without intercept for 7 secondary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.149*Students | 0.76 | 591 |
| Parked vehicles = 1.83*Employees | 0.75 | 652 |
| Parked vehicles = 4.98*Classes | 0.73 | 815 |
| Parked vehicles = 13.485*Floor area | 0.72 | 938 |
| Parked vehicles = 6.18*Lot area | 0.73 | 854 |

**Table 3.4: Summary of the developed models with intercept for 10 secondary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.085*Students+42.62 | 0.32 | 558 |
| Parked vehicles = 1.49*Employees+21 | 0.25 | 616 |
| Parked vehicles = 2.08*Classes+53.15 | 0.06 | 772 |
| Parked vehicles = 7.43*Floor area+42.06 | 0.08 | 762 |
| Parked vehicles = 2.12*Lot area+58.56 | -0.01 | 842 |

**Table 3.5: Summary of the developed models without intercept for 10 secondary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.16*Students | 0.79 | 830 |
| Parked vehicles = 1.97*Employees | 0.82 | 579 |
| Parked vehicles = 5.48*Classes | 0.86 | 1115 |
| Parked vehicles = 14.76*Floor area | 0.79 | 834 |
| Parked vehicles = 6.93*Lot area | 0.74 | 1200 |

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of ten schools without intercept were used as the final results to make it easy to compare with the international models which use ratios in most situations.

The remaining three schools which were not included in developing the models of seven schools without intercept were used to validate these models. Table 3.6 includes the observed values of dependent variable in the first column and the predicted values by the developed models of seven schools without intercept in the other columns.

**Table 3.6: Predicted values by different variables using the developed models (Secondary, Parking Generation)**

| **Number of parked vehicles** | Students (difference) | Employees (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) |
|---|---|---|---|---|---|
| Coefficient | 0.15 | 1.83 | 4.98 | 13.48 | 6.18 |
| 114 | 67(-41%) | 87(-24%) | 50(-56%) | 78(-32%) | 57(-50%) |
| 84 | 37(-56%) | 55(-34%) | 45(-46%) | 65(-23%) | 33(-61%) |
| 70 | 62(-11%) | 59(-16%) | 65(-7%) | 44(-37%) | 47(-33%) |
| **Average difference %** | 36 | 25 | 36 | 31 | 48 |
| **Range** | 11-56 | 16-34 | 7-56 | 23-37 | 33-61 |

*CV: coefficient of variation = Standard deviation / Mean*

$$Difference = \frac{\text{Predicted value} - \text{Observed value}}{\text{Observed value}} * 100\%$$

### *3.1.2.2 Discussion*

By comparing the models which resulted from the seven schools analysis with those that resulted from the ten schools analysis, it can be concluded that the study models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of ten schools analysis. On the other hand, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of parked vehicles when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which measures the average of the squares of the "errors" [28]. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

Based on Table 3.5 which summarized the results of analysis of ten schools without intercept and Table 3.6 which contains the predicted numbers of attracted vehicles using the developed models, the best model with the lowest mean square residual that predicts the number of parked vehicles at secondary schools is the following regression model:

**Model A: number of parked vehicles = 1.97 *Employees**

The model has the smallest mean square residual. The assumptions of normality, independency and equal variance of the model were checked graphically by considering the plot of residuals against the number of students, the plot of residuals against the total floor area, and the normality plot of residuals. All assumptions seemed to be reasonable.

The other models which are significant in predicting the number of parked vehicles were arranged in order (from the smallest mean square error to the largest one) as follows:

**Model B: number of parked vehicles = 0.16 * Number of Students**

**Model C: number of parked vehicles = 14.76 * Total Floor Area**

**Model D: number of parked vehicles = 5.48 * Number of Classes**

**Model E: number of parked vehicles = 6.93 * Total Lot Area**

The characteristics of these models are summarized in Table 3.7.

**Table 3.7: Characteristics of the developed models (Secondary, Parking Generation)**

| Model number | Variable | Coefficient | P-Value | **Mean square residual** |
|---|---|---|---|---|
| A | Employees | 1.97 | 1.79E-06 | 579 |
| B | Students | 0.16 | 9.17E-06 | 830 |
| C | Floor Area | 14.76 | 9.39E-06 | 834 |
| D | Classes | 5.48 | 3.53E-05 | 1115 |
| E | Lot Area | 6.93 | 4.93E-05 | 1200 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the independent variables and the normality plot of residuals. All assumptions seemed to be reasonable.

### 3.1.3 Data Analysis for Intermediary Schools

#### *3.1.3.1 Summary of Results*

The correlation between the dependent variable (parked vehicles) and independent variables for intermediary schools was introduced by the following matrix (Table 3.8).

**Table 3.8: Correlation matrix for the variables of intermediary schools (10 schools)**

| | *Parked* | *Total Attracted* | *Students* | *Class-rooms* | *Employees* | *Lot area* | *Floor area* | *Parking space area* | *Dist to nearest school* | *Dist to arterial* | *Dist to collector* | *Dist to CBD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parked | 1.00 | | | | | | | | | | | |
| Total Attracted | 0.84 | 1.00 | | | | | | | | | | |
| Students | 0.86 | 0.94 | 1.00 | | | | | | | | | |
| Classrooms | 0.70 | 0.64 | 0.73 | 1.00 | | | | | | | | |
| Employees | 0.84 | 0.88 | 0.91 | 0.65 | 1.00 | | | | | | | |
| Lot area | 0.62 | 0.83 | 0.76 | 0.25 | 0.85 | 1.00 | | | | | | |
| Floor area | 0.82 | 0.91 | 0.89 | 0.64 | 0.97 | 0.83 | 1.00 | | | | | |
| Parking space area | 0.37 | 0.49 | 0.54 | 0.09 | 0.74 | 0.80 | 0.66 | 1.00 | | | | |
| Dist to nearest school | 0.03 | 0.17 | 0.30 | 0.17 | 0.08 | 0.18 | 0.04 | 0.02 | 1.00 | | | |
| Dist to arterial | -0.08 | 0.16 | 0.17 | -0.16 | 0.05 | 0.17 | 0.02 | 0.32 | -0.21 | 1.00 | | |
| Dist to collector | 0.10 | 0.24 | 0.19 | -0.27 | -0.06 | 0.18 | -0.01 | -0.05 | 0.27 | 0.44 | 1.00 | |
| Dist to CBD | -0.05 | 0.09 | 0.11 | -0.19 | -0.18 | 0.01 | -0.21 | -0.10 | 0.26 | 0.65 | 0.86 | 1.00 |

From the correlation matrix, it is clear that the most significant variables which have a strong linear relationship with the dependent variable (parked vehicles) are the number of students, employees and floor area.

The relationships between the dependent variable y (parked vehicles) and independent variables for intermediary schools are summarized in Tables 3.9 to 3.12 as shown below.

**Table 3.9: Summary of the developed models with intercept for 7 intermediary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.0692*Students+7.7723 | 0.76 | 21.32 |
| Parked vehicles = 0.7956*Employees+4.7799 | 0.83 | 15.47 |
| Parked vehicles = 1.5464*Classes+12.985 | 0.31 | 61.84 |
| Parked vehicles = 5.1654*Floor area+15.967 | 0.76 | 21.22 |
| Parked vehicles = 1.1055*Lot area+25.235 | 0.39 | 54.48 |
| Parked vehicles = 0.72 +1.01*Employees-6.56*Dummy | 0.86 | 12.30 |

Where,

Dummy = 1, if parking lot areas are available, 0 otherwise

**Table 3.10: Summary of the developed models without intercept for 7 intermediary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.0862*Students | 0.82 | 22.42 |
| Parked vehicles = 0.9057*Employees | 0.82 | 14.45 |
| Parked vehicles = 2.3295*Classes | 0.80 | 61.83 |
| Parked vehicles = 8.5721*Floor area | 0.80 | 53.19 |
| Parked vehicles = 2.9417*Lot area | 0.72 | 199.05 |
| Parked vehicles = 1.03*Employees-6.78*Dummy | 0.86 | 12.30 |

Where,

Dummy = 1, if parking lot areas are available, 0 otherwise

**Table 3.11: Summary of the developed models with intercept for 10 intermediary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.0683*Students+7.1746 | 0.70 | 22.87 |
| Parked vehicles = 0.6772*Employees+8.9672 | 0.67 | 25.22 |
| Parked vehicles = 1.3613*Classes+15.778 | 0.43 | 44.18 |
| Parked vehicles = 4.7127*Floor area+16.749 | 0.64 | 28.00 |
| Parked vehicles = 1.0482*Lot area+23.755 | 0.31 | 53.05 |
| Parked vehicles = 3.65+1.001*Employees-9.964*Dummy | 0.80 | 15.16 |

Where,

Dummy = 1, if parking lot areas are available, 0 otherwise

**Table 3.12: Summary of the developed models without intercept for 10 intermediary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.085*Students | 0.87 | 23.96 |
| Parked vehicles = 0.90*Employees | 0.87 | 28.62 |
| Parked vehicles = 2.3973*Classes | 0.84 | 63.43 |
| Parked vehicles = 8.5479*Floor area | 0.84 | 64.72 |
| Parked vehicles = 2.9025*Lot area | 0.77 | 163.07 |
| Parked vehicles = 1.113*Employees-11.128*Dummy | 0.86 | 14.22 |

Where,

Dummy = 1, if parking lot areas are available, 0 otherwise

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of ten schools without intercept were used as the final results to make it easy to compare with the international models which use ratios in most situations.

### *3.1.3.2 Models Validation*

The remaining three schools which were not included in developing the models of seven schools without intercept were used to validate these models. Table 3.13 includes the observed values of dependent variable in the first column and the predicted values by the developed models of seven schools without intercept in the other columns.

**Table 3.13: Predicted values by different variables using the developed models (Intermediary, Parking Generation)**

| **Number of parked vehicles** | Students (difference) | Employees (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) | Employees + Dummy (difference) |
|---|---|---|---|---|---|---|
| Coefficient | 0.09 | 0.91 | 2.33 | 8.57 | 2.94 | 1.03,-6.78 |
| 30 | 24(-20%) | 19(-37%) | 17(-43%) | 16(-47%) | 16(-47%) | 22(-26%) |
| 28 | 34(+21%) | 34(+21%) | 23(-18%) | 35(+25%) | 33(+17%) | 31(+11%) |
| 28 | 32(+14%) | 33(+18%) | 28(0%) | 28(0%) | 35(+25%) | 30(+7%) |
| **Average difference %** | 18 | 25 | 20 | 24 | 30 | 15 |
| **Range %** | 14-21 | 18-37 | 0-43 | 0-47 | 17-47 | 7-26 |

*CV: coefficient of variation = Standard deviation / Mean*

$$\textit{Difference} = \frac{\text{Predicted value} - \text{Observed value}}{\text{Observed value}} * 100\%$$

### *3.1.3.3 Discussion*

By comparing the models which resulted from the seven schools analysis with those that resulted from the ten schools analysis, it can be concluded that the study models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of ten schools analysis. On the other hand, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of attracted vehicular trips to school when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which measures the average of the squares of the “errors” [28]. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

Based on Table 3.12 which summarized the result of analysis of ten schools without intercept and Table 3.13 which contains the predicted numbers of attracted vehicles using the developed models, the best multiple and simple regression models with the lowest mean square residual that explains the attraction behavior to secondary schools are as follows:

**Model A: number of attracted vehicles = 1.113*Employees-11.128*Dummy**

**Model B: number of parked vehicles = 0.085 * Number of Students**

The models have the smallest mean square residual. The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the number of classes, the plot of residuals against the total lot area, the plot of residuals against number employees, the plot of residuals against the total floor area, and the normality plot of residuals. All assumptions seemed to be reasonable.

The other models which are significant in predicting the number of parked vehicles at intermediary schools were arranged in order as follows:

**Model C: number of parked vehicles = 0.90 * Number of Employees**

**Model D: number of parked vehicles = 2.40 * Number of Classes**

**Model E: number of parked vehicles = 8.54 * Total Floor Area**

**Model F: number of parked vehicles = 2.90 * Total Lot Area**

The characteristics of these models are summarized in Table 3.14 as shown below.

**Table 3.14: Characteristics of the developed models (Intermediary, Parking Generation)**

| Model number | Variable | Coefficient | P-Value |
|---|---|---|---|
| A | Employees<br>Dummy | 1.113<br>-11.128 | 3.9E-07<br>1.0E-02 |
| B | Students | 0.085 | 2.78E-09 |
| C | Employees | 0.90 | 6.21E-09 |
| D | Classes | 2.40 | 2.25E-07 |
| E | Floor Area | 8.54 | 2.47E-07 |
| F | Lot Area | 2.90 | 1.63E-05 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the number of students and the normality plot of residuals. All assumptions seemed to be reasonable.

### 3.1.4 Data Analysis for Primary Schools (Parking Generation)

#### *3.1.4.1 Summary of Results*

The correlation between the dependent variable (parked vehicles) and independent variables for primary schools was introduced by the following matrix (Table 3.15).

**Table 3.15: Correlation matrix for the variables of primary schools (10 schools)**

| | *Parked* | *Total Attracted* | *Students* | *Classes* | *Employees* | *Lot area* | *Floor area* | *Parking space area* | *Dist to nearest school* | *Dist to arterial* | *Dist to collector* | *Dist to CBD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parked | 1.00 | | | | | | | | | | | |
| Total Attracted | 0.87 | 1.00 | | | | | | | | | | |
| Students | 0.91 | 0.85 | 1.00 | | | | | | | | | |
| Classes | 0.96 | 0.86 | 0.97 | 1.00 | | | | | | | | |
| Employees | 1.00 | 0.88 | 0.92 | 0.97 | 1.00 | | | | | | | |
| Lot area | 0.62 | 0.78 | 0.42 | 0.52 | 0.63 | 1.00 | | | | | | |
| Floor area | 0.84 | 0.87 | 0.78 | 0.83 | 0.86 | 0.80 | 1.00 | | | | | |
| Parking space area | 0.66 | 0.66 | 0.48 | 0.49 | 0.64 | 0.74 | 0.67 | 1.00 | | | | |
| Dist to nearest school | -0.57 | -0.46 | -0.57 | -0.56 | -0.56 | -0.26 | -0.62 | -0.45 | 1.00 | | | |
| Dist to arterial | 0.17 | 0.36 | 0.04 | 0.08 | 0.17 | 0.47 | 0.38 | 0.41 | -0.05 | 1.00 | | |
| Dist to collector | -0.17 | -0.02 | -0.16 | -0.17 | -0.16 | -0.02 | -0.11 | -0.06 | 0.58 | 0.65 | 1.00 | |
| Dist to CBD | -0.03 | 0.14 | -0.11 | -0.05 | -0.01 | 0.33 | 0.01 | 0.03 | 0.70 | 0.50 | 0.74 | 1.00 |

From the correlation matrix, it is clear that the most significant variables which have a strong linear relationship with the dependent variable (parked vehicles) are the number of employees.

The relationships between the dependent variable y (parked vehicles) and independent variables for primary schools are summarized in Tables 3.16 to 3.19 as shown below.

**Table 3.16: Summary of the developed models with intercept for 7 primary schools (Parking Generation)**

| **Model** | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|
| Parked vehicles = 0.072*Students+4.568 | 0.81 | 35.13 |
| Parked vehicles = 0.9714*Employees-0.7985 | 1.00 | 0.89 |
| Parked vehicles = 1.8698*Classes+0.903 | 0.95 | 8.72 |
| Parked vehicles = 8.2884*Floor area+9.4049 | 0.68 | 60.23 |
| Parked vehicles = 1.3258*Lot area+20.762 | 0.26 | 139.21 |
| Parked vehicles = -1.28-0.057*Classes+1.296*Employees-0.128*Lot area | 1.00 | 0.73 |

**Table 3.17: Summary of the developed models without intercept for 7 primary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.0826*Students | 0.81 | 33.42 |
| Parked vehicles = 0.95*Employees | 0.83 | 0.85 |
| Parked vehicles = 1.9185*Classes | 0.83 | 7.41 |
| Parked vehicles = 11.228*Floor area | 0.78 | 72.14 |
| Parked vehicles = 3.05*Lot area | 0.58 | 318.90 |

**Table 3.18: Summary of the developed models with intercept for 10 primary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.0678*Students+5.5205 | 0.78 | 28.14 |
| Parked vehicles = 0.9587*Employees-0.406 | 0.99 | 0.97 |
| Parked vehicles = 1.7082*Classes+3.4646 | 0.91 | 12.56 |
| Parked vehicles = 7.5405*Floor area+9.6892 | 0.66 | 46.77 |
| Parked vehicles = 1.3483*Lot area+20.256 | 0.314 | 95.32 |
| Parked vehicles = -1.37-0.625*Classes+1.32*Employees-0.130*Lot area | 0.99 | 0.38 |

**Table 3.19: Summary of the developed models without intercept for 10 primary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.081*Students | 0.86 | 30.10 |
| Parked vehicles = 0.9473*Employees | 0.89 | 0.89 |
| Parked vehicles = 1.902*Classes | 0.88 | 13.08 |
| Parked vehicles = 10.546*Floor area | 0.83 | 60.46 |
| Parked vehicles = 3.2233*Lot area | 0.66 | 248.16 |

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of ten schools without intercept were used as the final results to make it easy to compare with the international models which use ratios in most situations.

### *3.1.4.2 Models Validation*

The remaining three schools which were not included in developing the models of seven schools without intercept were used to validate these models. Table 3.20 includes the observed values of dependent variable in the first column and the predicted values by the developed models of seven schools without intercept in the other columns.

**Table 3.20: Predicted values by different variables using the developed models (Primary, Parking Generation)**

| **Number of parked vehicles** | Students (difference) | Employees (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) |
|---|---|---|---|---|---|
| Coefficient | 0.08 | 0.95 | 1.92 | 11.23 | 3.05 |
| 29 | 36(+24%) | 30(+3%) | 34(+17%) | 35(+21%) | 12(-59%) |
| 20 | 16(-20%) | 19(-5%) | 13(-35%) | 18(-10%) | 16(-20%) |
| 35 | 35(0%) | 35(0%) | 35(0%) | 45(+29%) | 31(-11%) |
| **Average difference %** | 15 | 3 | 17 | 20 | 30 |
| **Range** | 0-24 | 0-5 | 0-35 | 10-29 | 11-59 |

*CV: coefficient of variation = Standard deviation / Mean*

$$\textit{Difference} = \frac{\text{Predicted value} - \text{Observed value}}{\text{Observed value}} * 100\%$$

### *3.1.4.3 Discussion*

By comparing the models which resulted from the seven schools analysis with those that resulted from the ten schools analysis, it can be concluded that the study models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of ten schools analysis. On the other hand, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of parked vehicles when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which measures the average of the squares of the "errors" [28]. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

Based on Table 3.19 which summarized the results of analysis of ten schools without intercept and Table 3.20 which contains the predicted numbers of attracted vehicles using the developed models, the best model with the lowest mean square residual that predicts the number of parked vehicles at primary schools is the following regression model:

**Model A: number of parked vehicles = 0.95 * Number of Employees**

The model has the smallest mean square residual. The assumptions of normality, independency and equal variance of the model were checked graphically by considering the plot of residuals against the number of students, the plot of residuals against the total floor area, and the normality plot of residuals. All assumptions seemed to be reasonable.

The other models which are significant in predicting the number of parked vehicles were arranged in order (from the lowest mean square error to the largest one) as follows:

**Model B: number of parked vehicles = 1.90 * Number of Classes**

**Model C: number of parked vehicles = 0.081 * Number of students**

**Model D: number of parked vehicles = 10.55 * Total Floor Area**

**Model E: number of parked vehicles = 3.22 * Total Lot Area**

The characteristics of these models are summarized in Table 3.21.

**Table 3.21: Characteristics of the developed models (Primary, Parking Generation)**

| Model number | Variable | Coefficient | P-Value | **Mean square residual** |
|---|---|---|---|---|
| A | Employees | 0.95 | 2.96E-15 | 0.89 |
| B | Classes | 1.90 | 5.39E-10 | 13.08 |
| C | Students | 0.08 | 2.31E-08 | 30.10 |
| D | Floor Area | 10.55 | 5.38E-07 | 60.46 |
| E | Lot Area | 3.22 | 3.0E-04 | 248.16 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the independent variables and the normality plot of residuals. All assumptions seemed to be reasonable.

### 3.1.5 Data Analysis for All Levels Schools (Parking Generation)

#### *3.1.5.1 Summary of Results*

The simple regression analysis for all levels schools was done in the same procedure as each level of schools. The only difference is in multiple regression analysis which was done two times. The first time was done without distinguishing between the levels of schools. In the second multiple regression analysis, two dummy variables were used to distinguish between the levels of schools as follows:

Dummy1 = 1 if secondary school, 0 otherwise

Dummy2 = 1 if intermediary school, 0 otherwise

The correlation between the dependent variable (parked vehicles) and independent variables for all schools pooled together was introduced by the following matrix (Table 3.22).

**Table 3.22: Correlation matrix for the variables of all levels pooled together (30 schools)**

| | *Parked* | *Total Attracted* | *Students* | *Classes* | *Employees* | *Lot area* | *Floor area* | *Parking space area* | *Dist to nearest school* | *Dist to arterial* | *Dist to collector* | *Dist to CBD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parked | 1.00 | | | | | | | | | | | |
| Total Attracted | 0.42 | 1.00 | | | | | | | | | | |
| Students | 0.58 | 0.80 | 1.00 | | | | | | | | | |
| Classes | 0.24 | 0.66 | 0.82 | 1.00 | | | | | | | | |
| Employees | 0.57 | 0.84 | 0.81 | 0.69 | 1.00 | | | | | | | |
| Lot area | 0.39 | 0.72 | 0.51 | 0.31 | 0.70 | 1.00 | | | | | | |
| Floor area | 0.70 | 0.71 | 0.63 | 0.40 | 0.80 | 0.72 | 1.00 | | | | | |
| Parking space area | 0.46 | 0.53 | 0.47 | 0.30 | 0.62 | 0.70 | 0.60 | 1.00 | | | | |
| Dist to nearest school | 0.25 | -0.06 | -0.19 | -0.34 | -0.22 | -0.06 | 0.16 | 0.00 | 1.00 | | | |
| Dist to arterial | 0.03 | 0.24 | 0.07 | -0.04 | 0.10 | 0.32 | 0.16 | 0.31 | 0.13 | 1.00 | | |
| Dist to collector | -0.07 | -0.05 | -0.26 | -0.30 | -0.27 | -0.07 | -0.09 | -0.06 | 0.55 | 0.48 | 1.00 | |
| Dist to CBD | -0.04 | 0.04 | -0.15 | -0.17 | -0.24 | 0.04 | -0.09 | 0.01 | 0.61 | 0.43 | 0.77 | 1.00 |

From the correlation matrix, it is clear that the most significant variable which has a strong linear relationship with the dependent variable (parked vehicles) is floor area.

The relationships between the dependent variable y (parked vehicles) and independent variables for all levels schools are summarized in Tables 3.23 to 3.26 as shown below.

**Table 3.23: Summary of the developed models with intercept for 21 pooled schools (Parking Generation)**

| **Model** | **Adjusted $R^2$** | **Mean square residual** |
|---|---|---|
| Parked vehicles = 0.1113*Students+1.27 | 0.47 | 447 |
| Parked vehicles = 1.41*Employees-5.58 | 0.34 | 560 |
| Parked vehicles = 1.94*Classes+18.60 | 0.10 | 766 |
| Parked vehicles = 10.48*Floor area+5.88 | 0.49 | 438 |
| Parked vehicles = 2.58*Lot area+22.42 | 0.22 | 667 |
| Parked vehicles = 0.15*Students+4.84*Floor area-2.95*Classes+8.63 | 0.66 | 288 |
| Parked vehicles = 0.088*Students+35.60*Dummy1-0.78 | 0.81 | 164 |

where,

Dummy1 = 1 if secondary, 0 otherwise

**Table 3.24: Summary of the developed models without intercept for 21 pooled schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.114*Students | 0.82 | 425 |
| Parked vehicles = 1.278*Employees | 0.79 | 535 |
| Parked vehicles = 3.01*Classes | 0.71 | 771 |
| Parked vehicles = 11.63*Floor area | 0.82 | 423 |
| Parked vehicles = 4.29*Lot area | 0.72 | 757 |
| Parked vehicles = 0.15*Students+5.57*Floor area-2.45*Classes | 0.86 | 280 |
| Parked vehicles = 0.087*Students+35.57*Dummy1 | 0.90 | 155 |

where,

Dummy1 = 1 if secondary, 0 otherwise

**Table 3.25: Summary of the developed models with intercept for 30 pooled schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.105*Students+6.09 | 0.32 | 604 |
| Parked vehicles = 1.44*Employees-4.33 | 0.30 | 616 |
| Parked vehicles = 1.277*Classes+30.36 | 0.02 | 863 |
| Parked vehicles = 11.47*Floor area+3.67 | 0.49 | 464 |
| Parked vehicles = 2.25*Lot area+27.47 | 0.12 | 777 |
| Parked vehicles = 0.15*Students-3.26*Classes-1.83*Lot area+10.63*Floor area+9.96 | 0.62 | 332 |
| Parked vehicles = 0.08*Students+43.4*Dummy1+2.58 | 0.79 | 182 |

where,

Dummy1 = 1 if secondary, 0 otherwise

**Table 3.26: Summary of the developed models without intercept for 30 pooled schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.118*Students | 0.79 | 588 |
| Parked vehicles = 1.337*Employees | 0.79 | 596 |
| Parked vehicles = 3.14*Classes | 0.68 | 954 |
| Parked vehicles = 12.25*Floor area | 0.83 | 450 |
| Parked vehicles = 4.52*Lot area | 0.67 | 925 |
| Parked vehicles = 0.15*Students-2.82*Classes-1.73*Lot area+11.29*Floor area | 0.86 | 331 |
| Parked vehicles = 0.083*Students+43.5*Dummy1 | 0.91 | 177 |

where,

Dummy1 = 1 if secondary, 0 otherwise

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of ten schools without intercept were used as the final results to make it easy to compare with the international models which use ratios in most situations.

#### *3.1.5.2 Models Validation*

The remaining nine schools which were not included in developing the models were used to validate these models. Table 3.27 includes the observed values of dependent variable in the first column and the predicted values by all the developed models in the other columns.

**Table 3.27: Predicted values by different variables using the developed models (All Levels, Parking Generation)**

| **Number of parked vehicles** | Employees (difference) | Students (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) | Classes + Students + Floor Area (difference) | Students + Dummy1 (difference) |
|---|---|---|---|---|---|---|---|
| Coefficient | 1.28 | 0.11 | 3.01 | 11.63 | 4.29 | 0.15,5.57,2.45 | 0.09,35.57 |
| 114 | 61(-46%) | 51(-55%) | 30(-73%) | 67(-41%) | 40(-65%) | 75(-34%) | 75(-34%) |
| 84 | 38(-55%) | 29(-65%) | 27(-68%) | 56(-33%) | 23(-73%) | 42(-50%) | 57(-32%) |
| 70 | 40(-43%) | 47(-33%) | 39(-44%) | 38(-45%) | 33(-53%) | 48(-31%) | 71(+1%) |
| 30 | 27(-10%) | 32(+7%) | 21(-30%) | 21(-30%) | 23(-23%) | 35(+17%) | 24(-20%) |
| 28 | 47(+68%) | 44(+57%) | 30(+7%) | 48(+71%) | 48(+71%) | 57(+100%) | 34(+21%) |
| 28 | 46(+64%) | 43(+54%) | 36(+29%) | 38(+36%) | 50(+79%) | 45(+61%) | 33(+18%) |
| 29 | 41(+41%) | 50(+72%) | 54(+86%) | 36(+24%) | 16(-45%) | 39(+34%) | 38(+31%) |
| 20 | 26(+30%) | 21(+5%) | 21(+5%) | 19(-5%) | 22(+10%) | 20(0%) | 16(-20%) |
| 35 | 47(+34%) | 48(+37%) | 54(+54%) | 47(+34%) | 44(+25%) | 41(+17%) | 36(+3%) |
| **Average difference %** | **44** | **43** | **44** | **36** | 50 | 39 | 20 |
| **Range** | **10-68** | **5-72** | **5-86** | **5-71** | 10-79 | 0-100 | 1-34 |

#### *3.1.5.3 Discussion*

By comparing the models which resulted from the 21 schools analysis with those that resulted from the 30 schools analysis, it can be concluded that the study models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of 30 schools analysis. On the other hand, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of attracted vehicular trips to school when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which measures the average of the squares of the "errors" [28]. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

Based on Table 3.26 which summarized the results of analysis of 30 schools without intercept and Table 3.27 which contains the predicted numbers of attracted vehicles using the developed models, the best multiple and simple regression models with the lowest mean square residual that explains the attraction behavior to secondary schools are as follows:

**Model A: number of parked vehicles = 0.083*Students+43.5*Dummy1**

where, Dummy1 = 1 if secondary, 0 otherwise

**Model B: number of parked vehicles = 12.25 * Total Floor Area**

The model has the highly significant coefficients with P-values of 1.72E-12 for the coefficient of the number of students and 5.46E-9 for the dummy variable. The assumptions of normality, independency and equal variance of the model were checked graphically by considering the plot of residuals against the number of employees and the normality plot of residuals. All assumptions seemed to be reasonable.

The other models which are significant in predicting the number of parked vehicles at schools were arranged in order (from the smallest mean square residual to the largest one) as follows:

**Model C: number of parked vehicles = 0.15*Students-2.82*Classes-1.73*Lot Area+11.29*Floor Area**

**Model D: number of parked vehicles = 0.118 * Number of Students**

**Model E: number of parked vehicles = 1.337 * Number of Employees**

**Model F: number of parked vehicles = 4.52 * Total Lot Area**

**Model G: number of parked vehicles = 3.14 * Number of Classes**

The characteristics of these models are summarized in Table 3.28 as shown below.

**Table 3.28: Characteristics of the developed models (All Levels, Parking Generation)**

| Model number | Variable | Coefficient | P-Value | **Mean square residual** |
|---|---|---|---|---|
| A | Students<br>Dummy 1 | 0.083<br>43.50 | 1.72E-12<br>5.46E-9 | 177 |
| B | Floor Area | 12.25 | 4.19E-14 | 450 |
| C | Students<br>Lot Area<br>Classes<br>Floor Area | 0.15<br>1.73<br>-2.82<br>11.29 | 0.0023<br>0.0829<br>0.0096<br>0.0007 | 331 |
| D | Students | 0.118 | 2.03E-12 | 588 |
| E | Employees | 1.337 | 2.48E-12 | 596 |
| F | Lot Area | 4.52 | 1.55E-9 | 925 |
| G | Classes | 3.14 | 2.44E-09 | 954 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the independent variables and the normality plot of residuals. All assumptions seemed to be reasonable.

From **model A**, it is clear that the secondary schools have the significant effect because of the appearance of the dummy variable which is related to secondary schools. Because of that, another trial of analysis in which the primary and intermediary schools were pooled together, was performed as shown in the next section.

### 3.1.6 Data Analysis for Primary & Intermediary Schools

#### *3.1.6.1 Summary of Results*

The correlation between the dependent variable (parked vehicles) and independent variables for primary and intermediary schools was introduced by the following matrix (Table 3.29).

**Table 3.29: Correlation matrix for the variables of primary & intermediary schools together (20 schools)**

| | *Parked* | *Total Attracted* | *Students* | *Class-rooms* | *Employees* | *Lot area* | *Floor area* | *Parking space area* | *Dist to nearest school* | *Dist to arterial* | *Dist to collector* | *Dist to CBD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parked | 1.00 | | | | | | | | | | | |
| Total Attracted | 0.84 | 1.00 | | | | | | | | | | |
| Students | 0.89 | 0.85 | 1.00 | | | | | | | | | |
| Classrooms | 0.80 | 0.64 | 0.85 | 1.00 | | | | | | | | |
| Employees | 0.94 | 0.88 | 0.91 | 0.76 | 1.00 | | | | | | | |
| Lot area | 0.65 | 0.82 | 0.57 | 0.34 | 0.76 | 1.00 | | | | | | |
| Floor area | 0.82 | 0.90 | 0.80 | 0.60 | 0.91 | 0.83 | 1.00 | | | | | |
| Parking space area | 0.55 | 0.56 | 0.51 | 0.31 | 0.68 | 0.76 | 0.65 | 1.00 | | | | |
| Dist to nearest school | -0.36 | -0.15 | -0.31 | -0.37 | -0.30 | -0.07 | -0.28 | -0.27 | 1.00 | | | |
| Dist to arterial | 0.11 | 0.29 | 0.11 | -0.03 | 0.16 | 0.36 | 0.24 | 0.38 | -0.08 | 1.00 | | |
| Dist to collector | -0.13 | 0.02 | -0.10 | -0.17 | -0.16 | -0.01 | -0.12 | -0.07 | 0.50 | 0.54 | 1.00 | |
| Dist to CBD | -0.04 | 0.10 | -0.03 | -0.10 | -0.09 | 0.16 | -0.10 | -0.04 | 0.53 | 0.55 | 0.74 | 1.00 |

From the correlation matrix, it is clear that the most significant variables which have a strong linear relationship with the dependent variable (parked vehicles) are the number of employees, students and floor area.

The relationships between the dependent variable y (parked vehicles) and independent variables for primary and intermediary schools pooled together are summarized in Tables 3.30 to 3.33 as shown below.

**Table 3.30: Summary of the developed models with intercept for 14 schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.072*Students+5.25 | 0.82 | 25 |
| Parked vehicles = 0.89*Employees+1.35 | 0.94 | 8 |
| Parked vehicles = 1.79*Classes+5.60 | 0.68 | 44 |
| Parked vehicles = 5.97*Floor area+13.93 | 0.70 | 42 |
| Parked vehicles = 1.28*Lot area+22.17 | 0.41 | 83 |
| Parked vehicles = 0.73*Employees+0.48*Classes-0.38 | 0.96 | 5 |

**Table 3.31: Summary of the developed models without intercept for 14 schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.085*Students | 0.90 | 27 |
| Parked vehicles = 0.93*Employees | 0.92 | 8 |
| Parked vehicles = 2.11*Classes | 0.89 | 44 |
| Parked vehicles = 9.35*Floor area | 0.87 | 79 |
| Parked vehicles = 2.98*Lot area | 0.75 | 239 |
| Parked vehicles = 0.73*Employees+0.47*Classes | 0.91 | 5 |

**Table 3.32: Summary of the developed models with intercept for 20 schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.07*Students+5.90 | 0.78 | 23 |
| Parked vehicles = 0.83*Employees+3.47 | 0.87 | 14 |
| Parked vehicles = 1.51*Classes+10.10 | 0.63 | 41 |
| Parked vehicles = 5.66*Floor area+13.90 | 0.65 | 38 |
| Parked vehicles = 1.23*Lot area+21.46 | 0.40 | 67 |
| Parked vehicles = 0.68*Employees+0.40*Classes+2.61 | 0.88 | 13 |

**Table 3.33: Summary of the developed models without intercept for 20 schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.083*Students | 0.93 | 26 |
| Parked vehicles = 0.92*Employees | 0.93 | 15 |
| Parked vehicles = 2.12*Classes | 0.90 | 51 |
| Parked vehicles = 9.22*Floor area | 0.89 | 71 |
| Parked vehicles = 3.02*Lot area | 0.78 | 197 |
| Parked vehicles = 0.73*Employees+0.45*Classes | 0.93 | 13 |

When the results of analysis using intercept and the results of analysis without intercept were compared, it was obvious that the coefficients of independent variables were not significantly different. The results of ten schools without intercept were used as the final results to make it easy to compare with the international models which use ratios in most situations.

### *3.1.6.2 Models Validation*

The remaining three schools which were not included in developing the models of seven schools without intercept were used to validate these models. Table 3.34 includes the observed values of dependent variable in the first column and the predicted values by the developed models of seven schools without intercept in the other columns.

**Table 3.34: Predicted values by different variables using the developed models (Primary & Intermediary, Parking Generation)**

| **Number of parked vehicles** | Students (difference) | Employees (difference) | Classes (difference) | Floor Area (difference) | Lot Area (difference) | Employees + Classes (difference) |
|---|---|---|---|---|---|---|
| Coefficient | 0.085 | 0.93 | 2.11 | 9.35 | 2.98 | 0.73,0.47 |
| 30 | 24(-20%) | 20(-33%) | 15(-50%) | 17(-43%) | 16(-47%) | 19(-37%) |
| 28 | 33(+18%) | 34(+21%) | 21(-25%) | 38(+36%) | 33(+18%) | 32(+14%) |
| 28 | 32(+14%) | 33(+18%) | 25(-10%) | 31(+11%) | 35(+25%) | 32(+14%) |
| 29 | 37(+28%) | 30(+3%) | 38(+31%) | 29(0%) | 11(-62%) | 32(+10%) |
| 20 | 16(-20%) | 19(-5%) | 15(-25%) | 15(-25%) | 15(-25%) | 18(-10%) |
| 35 | 36(+3%) | 34(-3%) | 38(+9%) | 38(+9%) | 30(-14%) | 35(0%) |
| **Average difference %** | 17 | 14 | 25 | 21 | 32 | 14 |
| **Range%** | 2-28 | 3-33 | 9-50 | 0-43 | 14-62 | 0-37 |

### *3.1.6.3 Discussion*

By comparing the models which resulted from the 14 schools analysis with those that resulted from the 20 schools analysis, it can be concluded that the study models are stable since there is a small difference between the coefficients of independent variables. Based on that, the study depended on the results of 20 schools analysis. On the other hand, there is no significant difference in the coefficients of independent variables between the models built using the intercept and those in which the intercept was forced to be zero. This study depended on the models in which the intercept was forced to be zero to make it easier to compare the results with the local and international models. Furthermore, it is impractical to have a number of attracted vehicular trips to school when one of the independent variables is zero. The statistical measure of goodness of fit of the regression models that was used in this study is the mean square residual which is measures the average of the squares of the "errors" [28]. The mean square error was used as a measure of goodness of fit rather than the coefficient of determination ($R^2$) to make it possible to compare between the models with intercept and those models without intercept.

Based on Table 3.33 which summarized the results of analysis of 20 schools without intercept and Table 3.34 which contains the predicted numbers of attracted vehicles using the developed models, the best multiple and simple regression models with the lowest mean square residual that explains the attraction behavior to secondary schools are as follows:

**Model A: number of parked vehicles = 0.73*Employees+0.45*Classes**

**Model B: number of parked vehicles = 0.92 * Number of Employees**

The model has the highly significant coefficients with P-values of 4.75E-07 for the number of employees and 6.2E-03 for the number of classes. The model has the smallest mean square residual and largest F-value. The assumptions of normality, independency and equal variance of the model were checked graphically by considering the plot of residuals against the number of students, the plot of residuals against the total lot area, and the normality plot of residuals. All assumptions seemed to be reasonable.

The other models which are significant in predicting the number of parked vehicles at primary and intermediary schools were arranged in order (from the smallest mean square error to the largest one) as follows:

**Model C: number of parked vehicles = 0.083 * Number of Students**

**Model D: number of parked vehicles = 2.12 * Number of Classes**

**Model E: number of parked vehicles = 9.22 * Total Floor Area**

**Model F: number of parked vehicles = 3.02 * Total Lot Area**

The characteristics of these models are summarized in Table 3.35 as shown below.

**Table 3.35: Characteristics of the developed models (Primary & Intermediary, Parking Generation)**

| Model number | Variable | Coefficient | P-Value | **Mean square residual** |
|---|---|---|---|---|
| A | Employees<br>Classes | 0.73<br>0.45 | 4.75E-07<br>6.2E-03 | 13 |
| B | Employees | 0.92 | 1.41E-19 | 15 |
| C | Students | 0.083 | 3.17E-17 | 26 |
| D | Classes | 2.12 | 1.980E-14 | 51 |
| E | Floor Area | 9.22 | 4.17E-13 | 71 |
| F | Lot Area | 3.02 | 7.150E-09 | 197 |

The assumptions of normality, independency and equal variance of the models were checked graphically by considering the plot of residuals against the independent variables and the normality plot of residuals. All assumptions seemed to be reasonable.

## 3.2 Summary of Results

Tables 3.36 to 3.40 represent the best models developed by the study for each type of analysis with their coefficient of determination and mean square residual.

**Table 3.36: Summary of the developed models for 10 secondary schools (parking generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 1.97*Employees | 0.82 | 579 |
| Parked vehicles = 0.16*Students | 0.79 | 830 |
| Parked vehicles = 14.76*Floor area | 0.79 | 834 |
| Parked vehicles = 5.48*Classes | 0.86 | 1115 |
| Parked vehicles = 6.93*Lot area | 0.74 | 1200 |

**Table 3.37: Summary of the developed models for 10 intermediary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.085*Students | 0.87 | 23.96 |
| Parked vehicles = 0.90* Employees | 0.87 | 28.62 |
| Parked vehicles = 2.3973*Classes | 0.84 | 63.43 |
| Parked vehicles = 8.5479*Floor area | 0.84 | 64.72 |
| Parked vehicles = 2.9025*Lot area | 0.77 | 163.07 |
| Parked vehicles = 1.113*Employees-11.128*Dummy | 0.86 | 14.22 |

**Table 3.38: Summary of the developed models for 10 primary schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.081*Students | 0.86 | 30.10 |
| Parked vehicles = 0.9473*Employees | 0.89 | 0.89 |
| Parked vehicles = 1.902*Classes | 0.88 | 13.08 |
| Parked vehicles = 10.546*Floor area | 0.83 | 60.46 |
| Parked vehicles = 3.2233*Lot area | 0.66 | 248.16 |

**Table 3.39: Summary of the developed models for 30 pooled schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.118*Students | 0.79 | 588 |
| Parked vehicles = 1.337*Employees | 0.79 | 596 |
| Parked vehicles = 3.14*Classes | 0.68 | 954 |
| Parked vehicles = 12.25*Floor area | 0.83 | 450 |
| Parked vehicles = 4.52*Lot area | 0.67 | 925 |
| Parked vehicles = 0.15*Students-2.82*Classes-1.73*Lot area+11.29*Floor area | 0.86 | 331 |
| Parked vehicles = 0.083*Students+43.5*Dummy1 | 0.91 | 177 |

**Table 3.40: Summary of the developed models without intercept for 20 schools (Parking Generation)**

| Model | Adjusted $R^2$ | Mean square residual |
|---|---|---|
| Parked vehicles = 0.083*Students | 0.93 | 26 |
| Parked vehicles = 0.92*Employees | 0.93 | 15 |
| Parked vehicles = 2.12*Classes | 0.90 | 51 |
| Parked vehicles = 9.22*Floor area | 0.89 | 71 |
| Parked vehicles = 3.02*Lot area | 0.78 | 197 |
| Parked vehicles = 0.73*Employees+0.45*Classes | 0.93 | 13 |

# CHAPTER 4

# QUESTIONNAIRE SURVEY ANALYSIS

## 4.1 Introduction

A questionnaire survey was conducted with the students for secondary schools and with the students' parents for intermediary and primary schools to study the socioeconomic characteristics of the students and to evaluate the appropriateness of some remedies in alleviating school congestion in the study area.

## 4.2 Procedure

The questionnaire was distributed over the 30 schools of the study. One hundred questionnaires were distributed for each school with a total of 3000 questionnaires. Tables 4.1 to 4.4 show the number of distributed, returned, invalid and analyzed questionnaires for each level of schools.

**Table 4.1: Questionnaire statistics for secondary schools**

| | |
|---|---|
| Distributed questionnaires | 1000 |
| Returned questionnaires | 757 |
| Invalid questionnaires | 24 |
| Analyzed questionnaires | 733 |
| % Analyzed | 73% |

**Table 4.2: Questionnaire statistics for intermediary schools**

| | |
|---|---|
| Distributed questionnaires | 1000 |
| Returned questionnaires | 532 |
| Invalid questionnaires | 22 |
| Analyzed questionnaires | 510 |
| % Analyzed | 51% |

**Table 4.3: Questionnaire statistics for primary schools**

| | |
|---|---|
| Distributed questionnaires | 1000 |
| Returned questionnaires | 572 |
| Invalid questionnaires | 12 |
| Analyzed questionnaires | 560 |
| % Analyzed | 56% |

**Table 4.4: Questionnaire statistics for all levels**

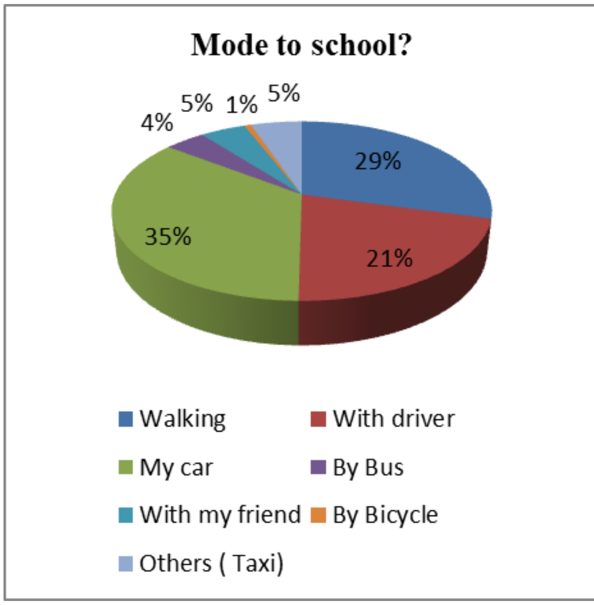
| | |
|---|---|
| Distributed questionnaires | 3000 |
| Returned questionnaires | 1861 |
| Invalid questionnaires | 58 |
| Analyzed questionnaires | 1803 |
| % Analyzed | 60% |

The invalid questionnaires are those which have some conflicts in the answers. (For example, when the student answered the question about the distance from home to school with 5-7 km and then answered the question about the time to arrive to school with 60 min, it means that he needs 60 min to pass a distance of 5-7 km by car, which is not reasonable.) It is obvious that the percentage of analyzed questionnaires for secondary schools is higher than those for primary and intermediary since the secondary school students filled the questionnaire by themselves, but for primary and intermediary, it was filled by the parents.

## 4.3 Descriptive Analysis

A descriptive analysis is a conclusion technique that is used to describe some key features of data in a research study. It gives a simple summary about a sample from the study. The following charts (Figures 4.1 to 4.56) present the results of analysis for each level of schools.

### 4.3.1 Secondary Schools



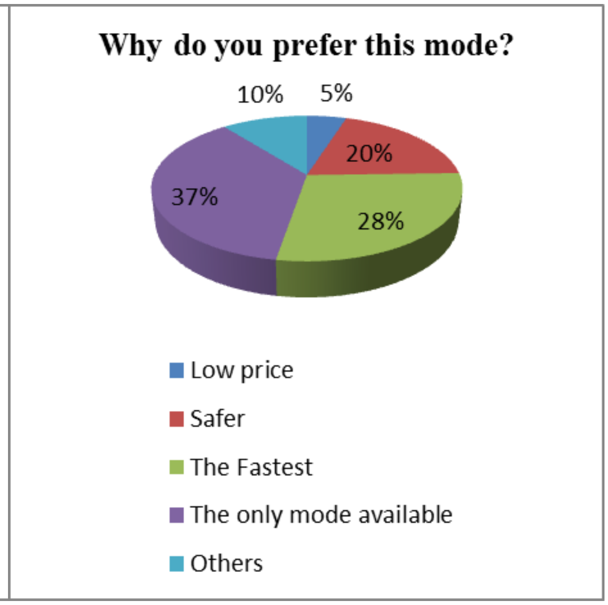




**Figure 4.1: Mode to school** **Figure 4.2: The reason for choosing this mode**

From Figure 4.1, it is clear that 56% of the students of secondary schools are coming to the schools by passenger cars.

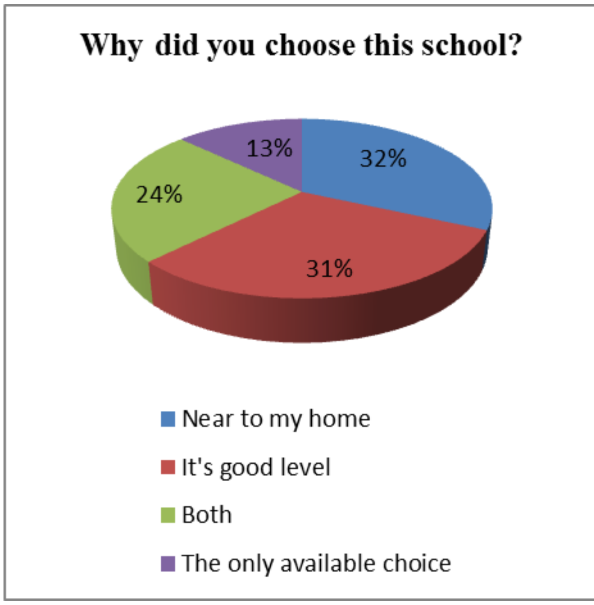



Figure 4.3: The reason for choosing this school

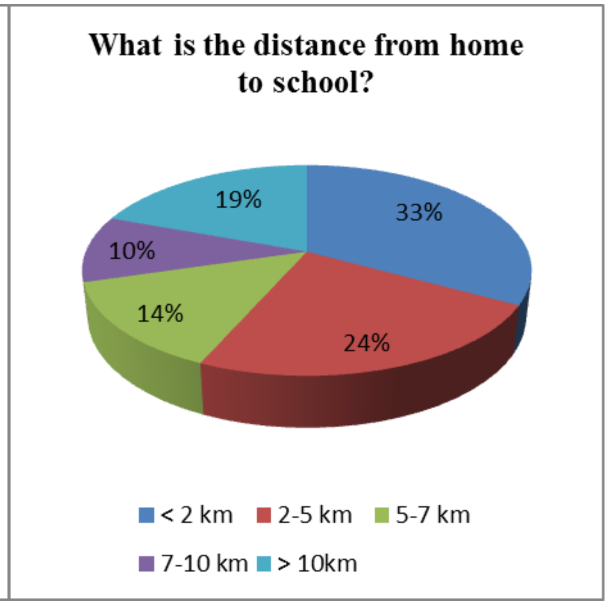



Figure 4.4: Distance from home to school

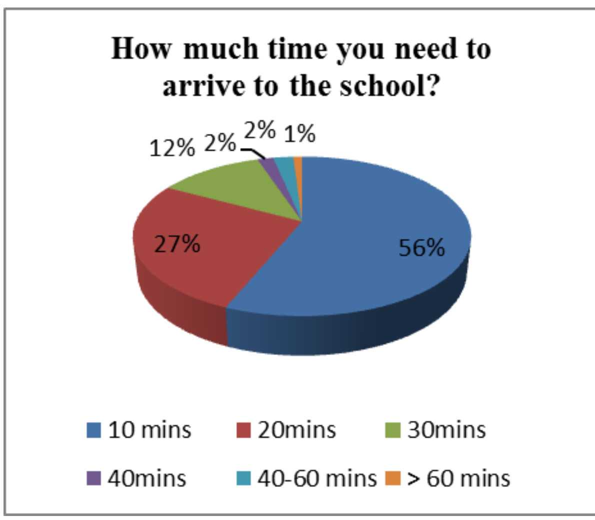



Figure 4.5: Time required to arrive to the school

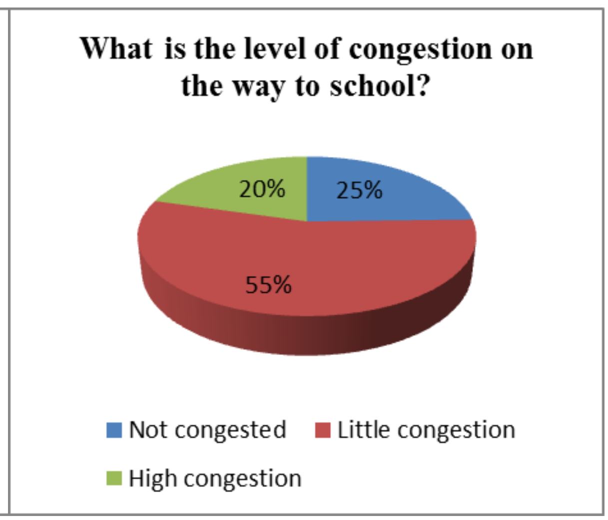



Figure 4.6: Level of congestion on the way to school

From Figures 4.4 and 4.5, the average distance from home to school is 4.89 km, and the average time required to arrive to the school is 17 min.

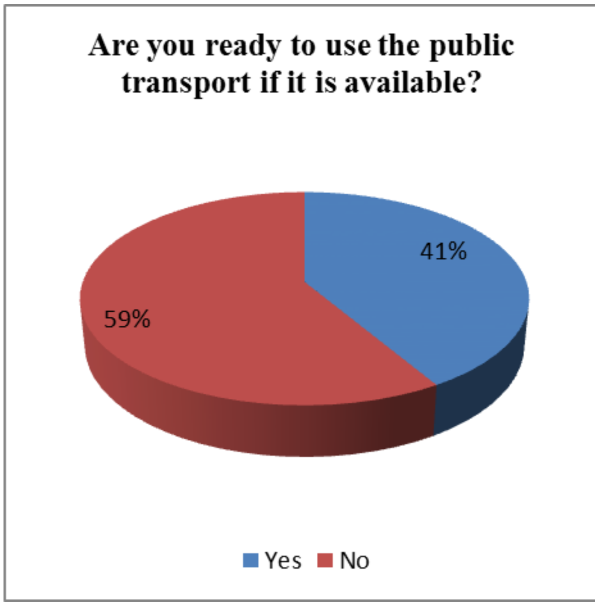



**Figure 4.7: Willingness to use public transport**

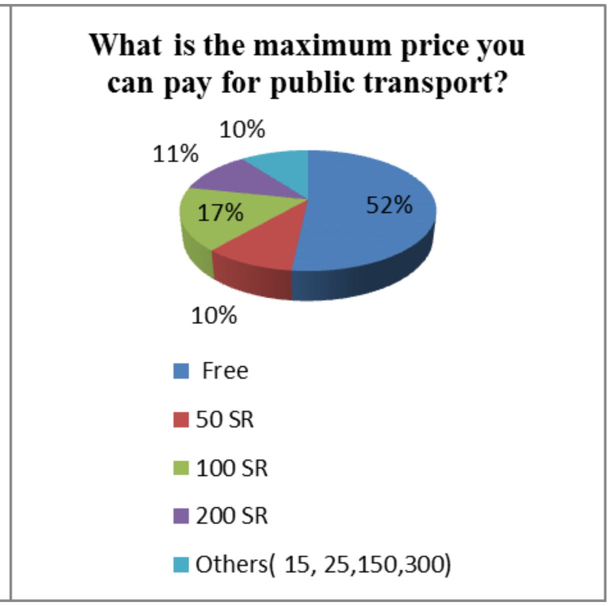
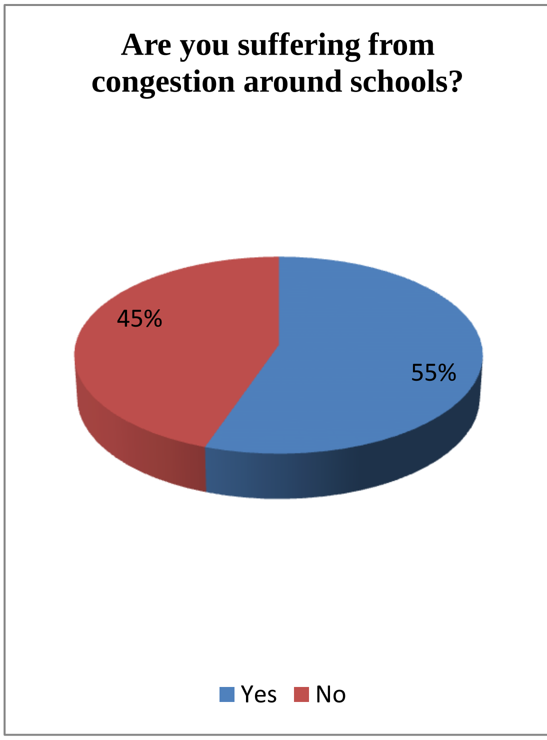



**Figure 4.8: The maximum price for public transport**

From Figures 4.7 and 4.8, 41% of students of secondary schools are ready to use public transportation, and 52% of them prefer this service to be free.



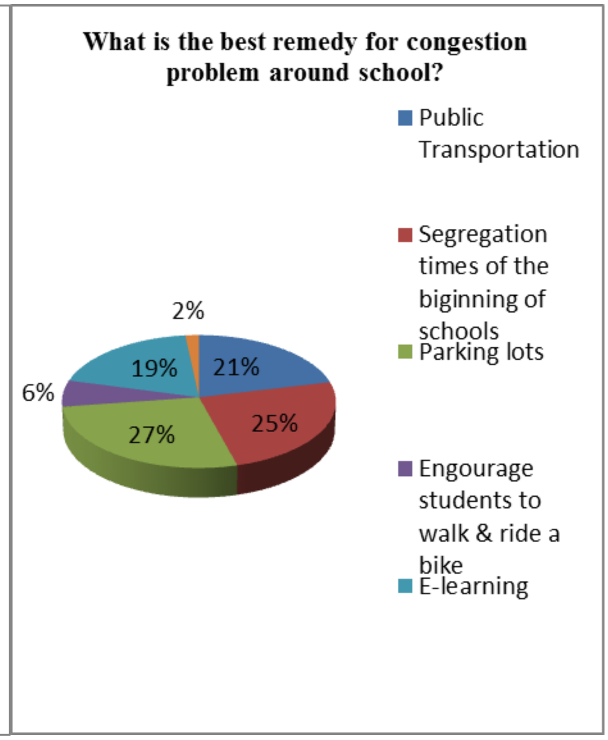
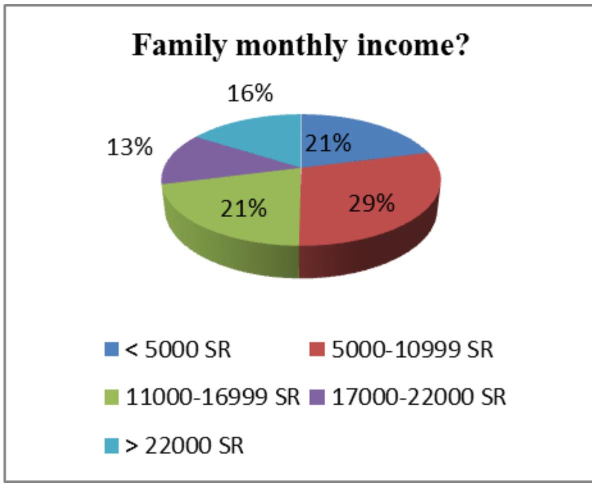




**Figure 4.9: Suffering from congestion**

**Figure 4.10: Best remedies to solve congestion problem**

According to the students of secondary schools, the best remedies to solve the congestion problem are providing the schools with more parking lots, segregation times of the beginning of schools, and public transportation, as shown in Figure 4.10.



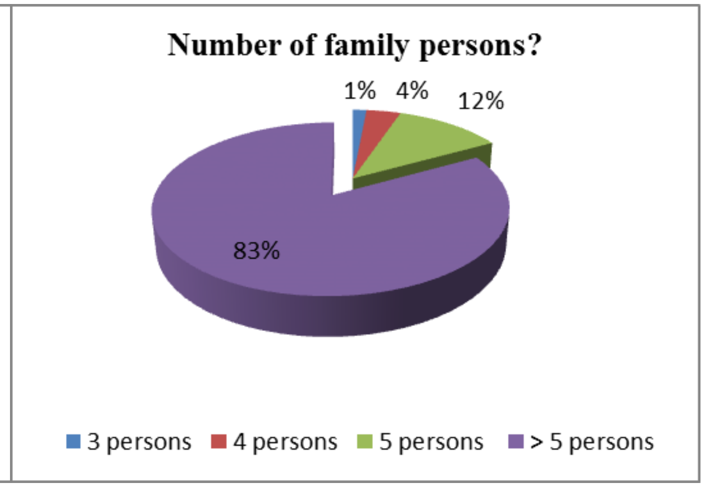
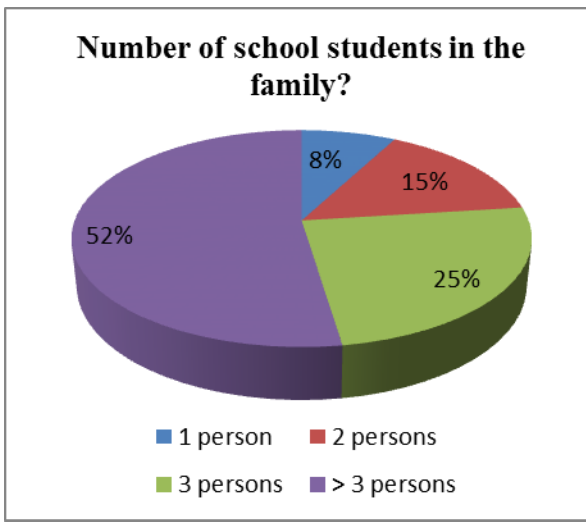




**Figure 4.11: Family monthly income**

**Figure 4.12: Number of family persons**



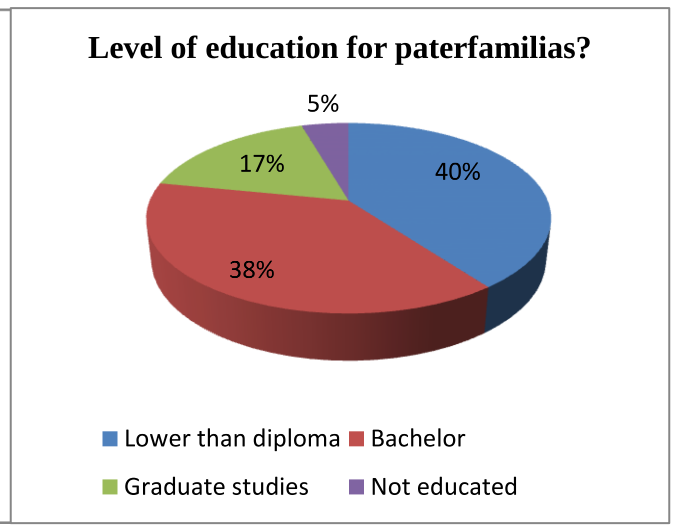




**Figure 4.13: Number of students in the family**

**Figure 4.14: Level of education for paterfamilias**

The weighted average for the family monthly income for students of secondary schools is 12400 SR as shown in Figure 4.11.

### 4.3.2 Intermediary Schools

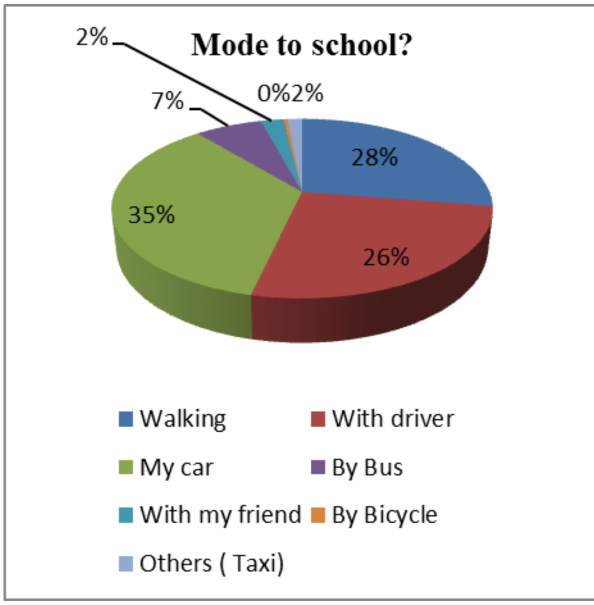



Figure 4.15: Mode to school

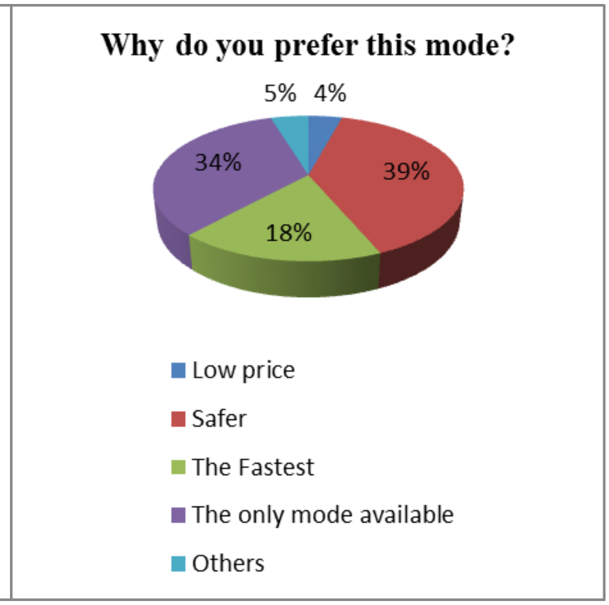



Figure 4.16: The reason for choosing this mode

From Figure 4.15, it is clear that 61% of the students of intermediary schools are coming to the schools by passenger cars.

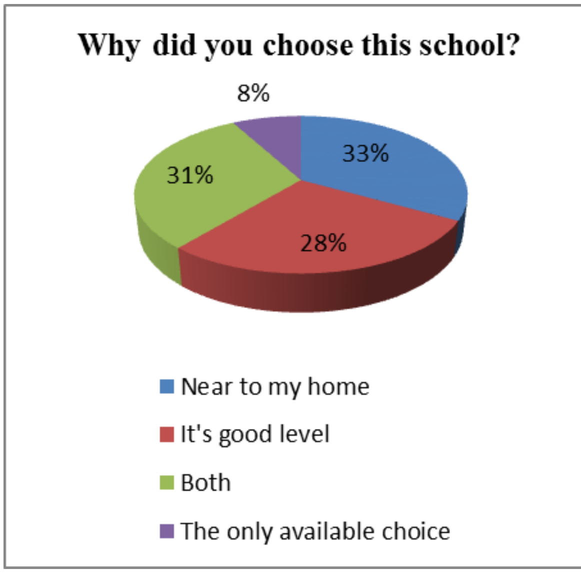



Figure 4.17: The reason for choosing this school

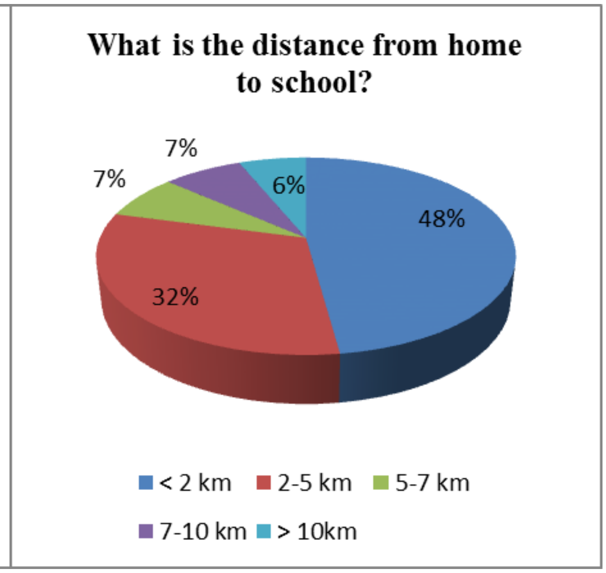



Figure 4.18: Distance from home to school

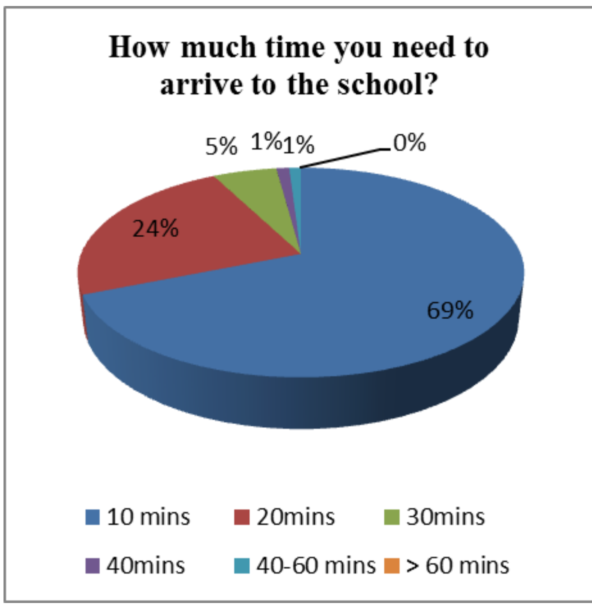



Figure 4.19: Time required to arrive to the school

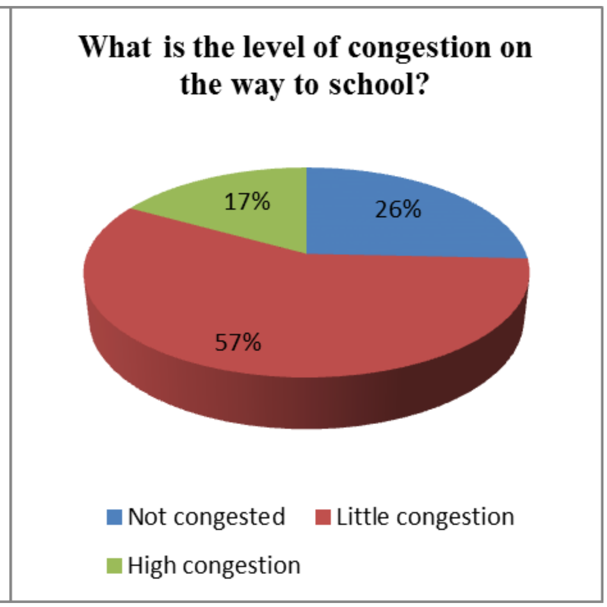
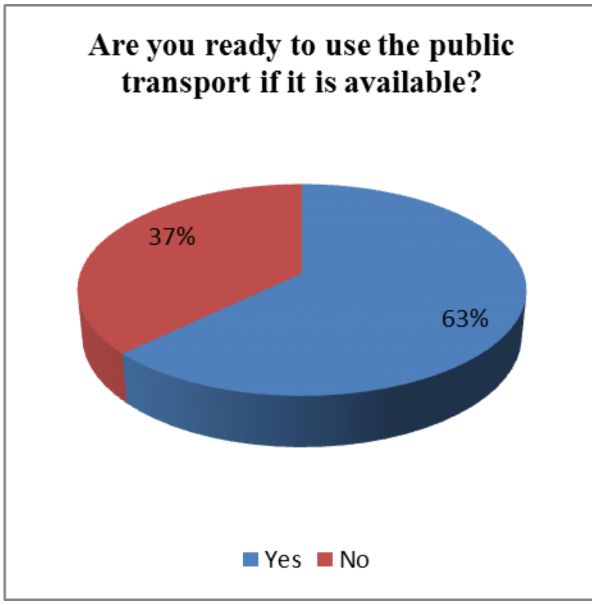



Figure 4.20: Level of congestion on the way to school

From Figures 4.18 and 4.19, the average distance from home to school is 3.70 km, and the average time required to arrive to the school is 14 min.



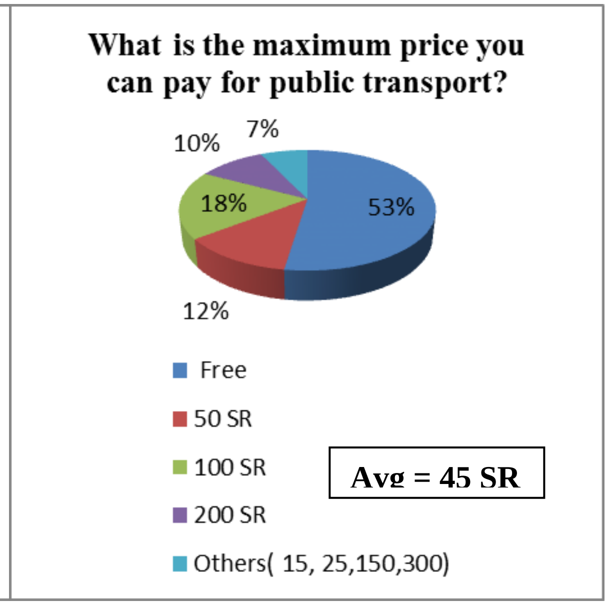
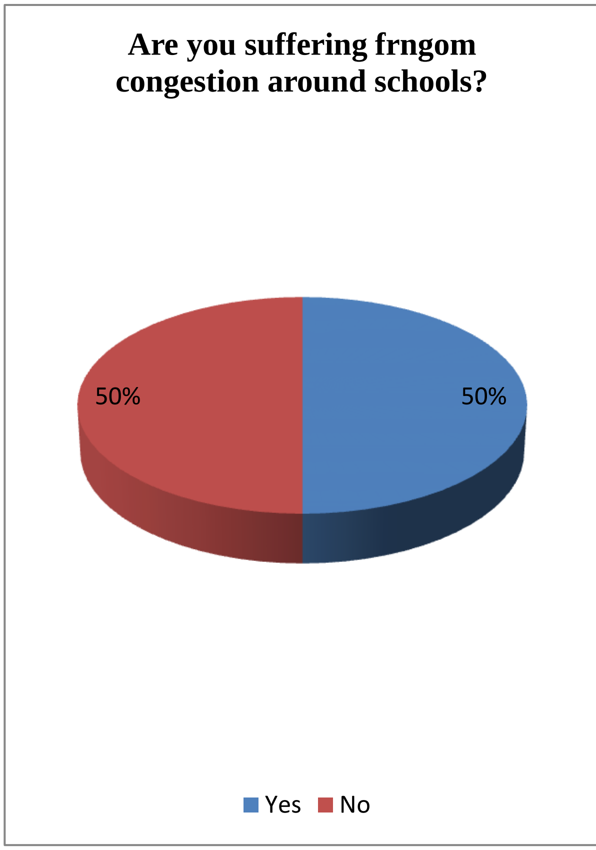




**Figure 4.21: Willingness to use public transport** **Figure 4.22: The maximum price for public transport**

From Figures 4.21 and 4.22, 63% of the students of intermediary schools are ready to use public transportation, and 53% of them prefer this service to be free.



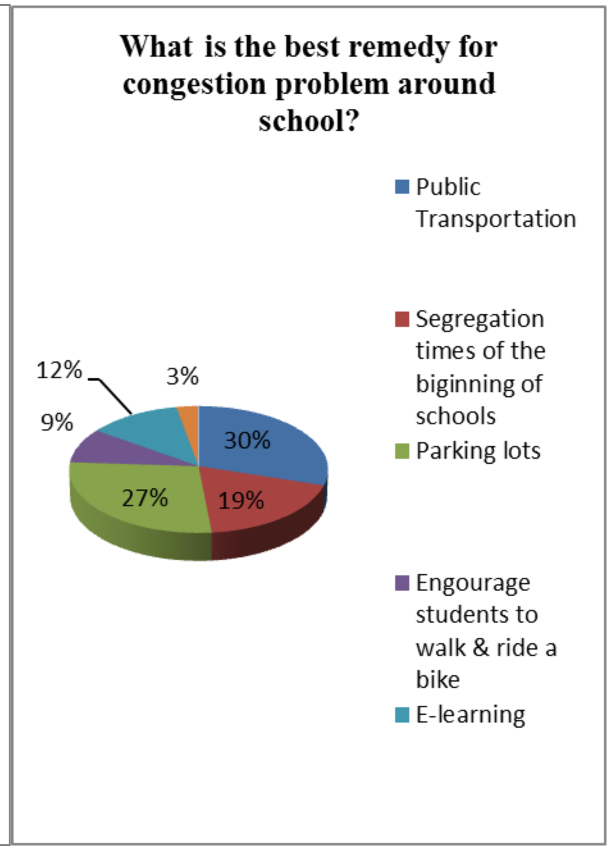




**Figure 4.23: Suffering from congestion**

**Figure 4.24: Best remedies to solve congestion problem**

According to the parents of students of intermediary schools, the best remedies to solve the congestion problem are providing the schools with more parking lots, segregation times of the beginning of schools, and public transportation, as shown in Figure 4.24.

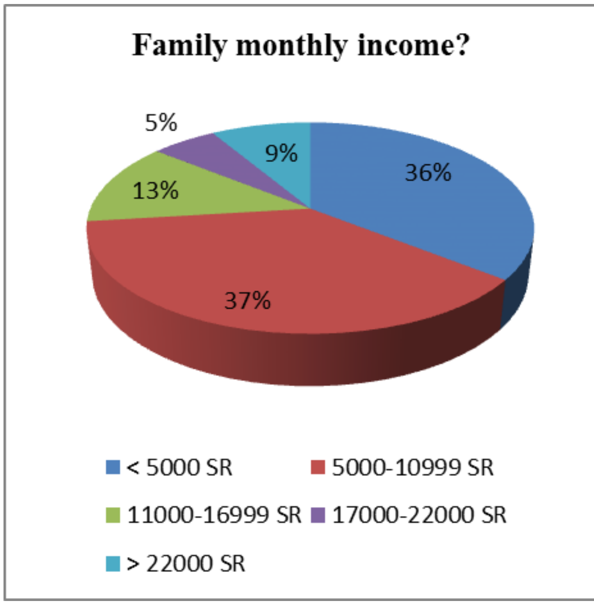



**Figure 4.25: Family monthly income**

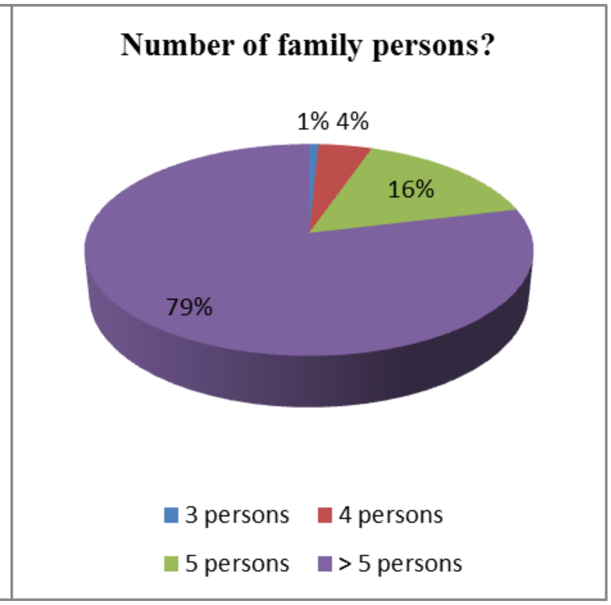



**Figure 4.26: Number of family persons**

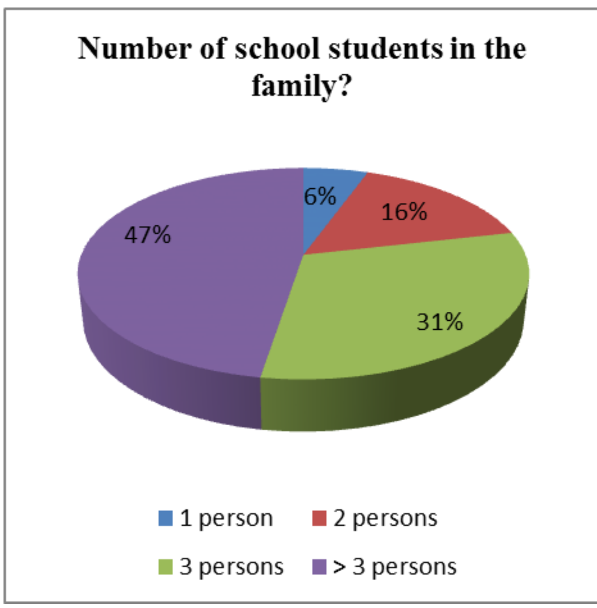



**Figure 4.27: Number of students in the family**

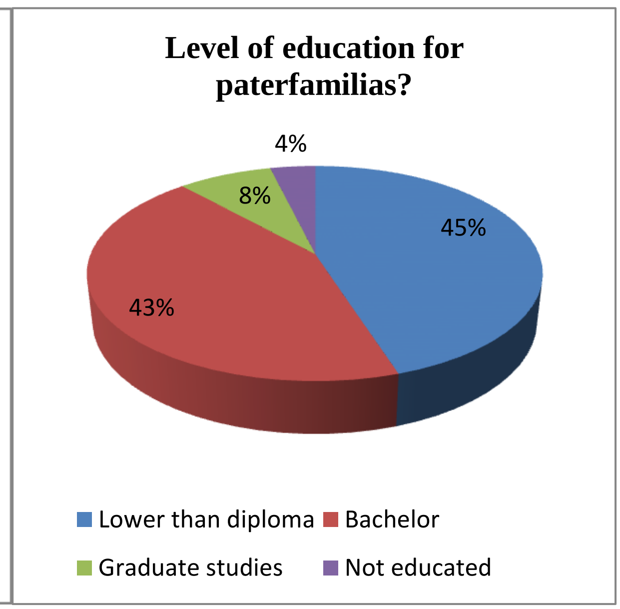



**Figure 4.28: Level of education for paterfamilias**

The weighted average for the family monthly income for students of intermediary schools is 9600 SR as shown in Figure 4.25.

### 4.3.3 Primary Schools

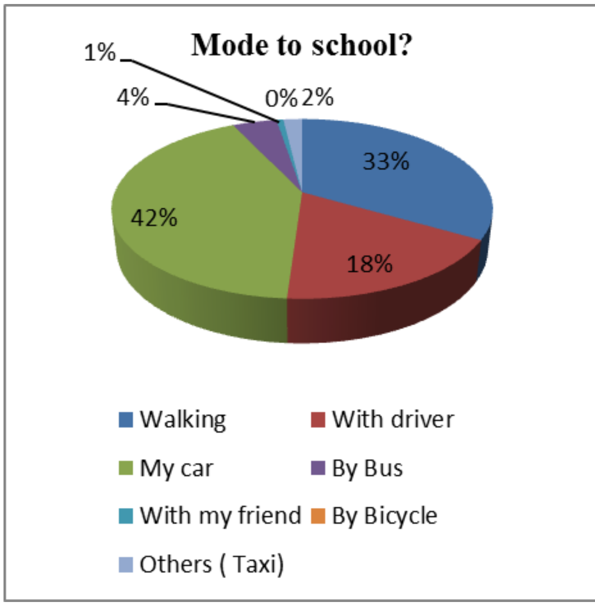



Figure 4.29: Mode to school

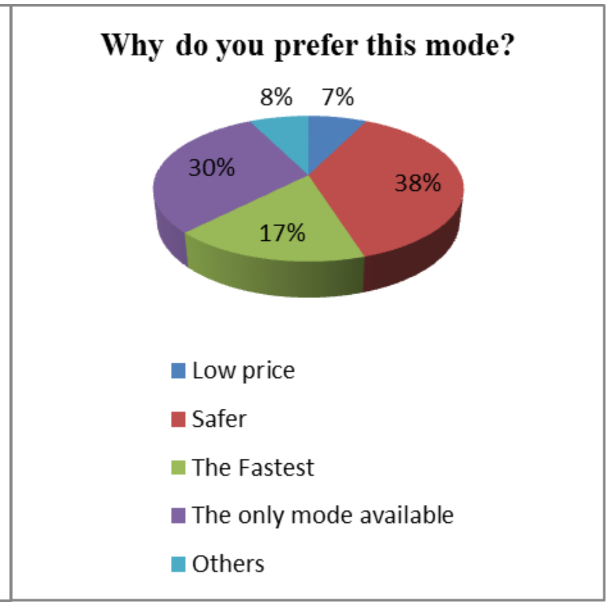



Figure 4.30: The reason for choosing this mode

From Figure 4.29, it is clear that 60% of the students of primary schools are coming to the schools by passenger cars.

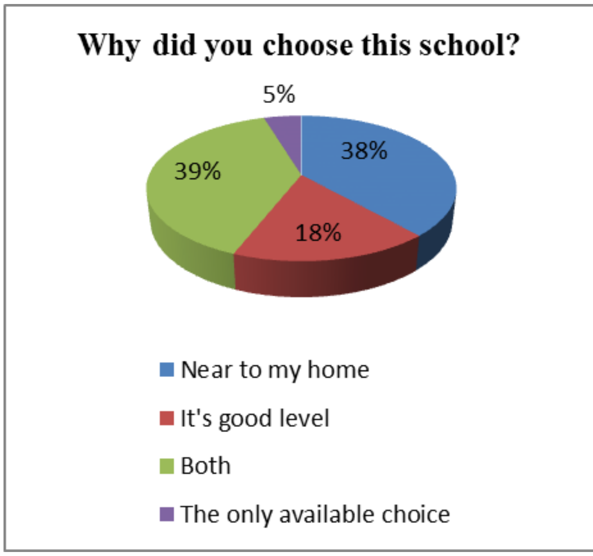



Figure 4.31: The reason for choosing this school

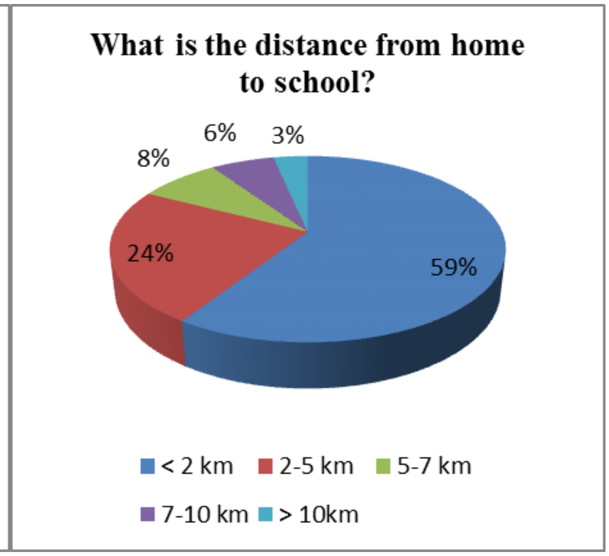



Figure 4.32: Distance from home to school

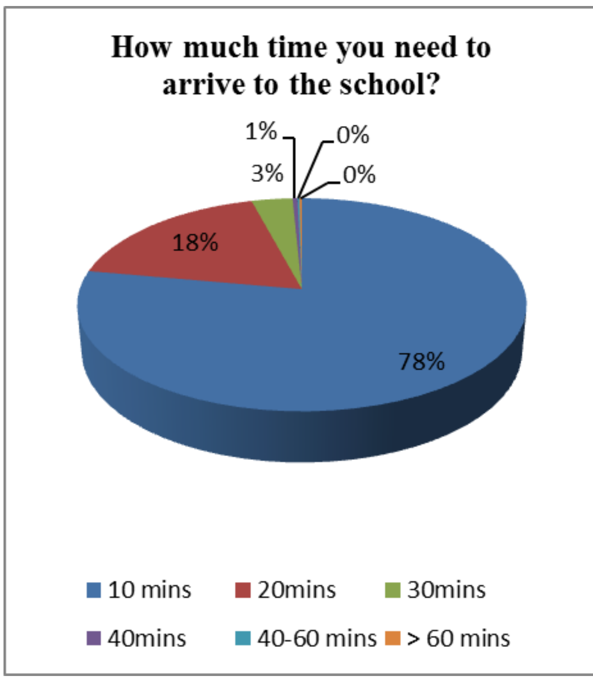



Figure 4.33: Time required to arrive to the school

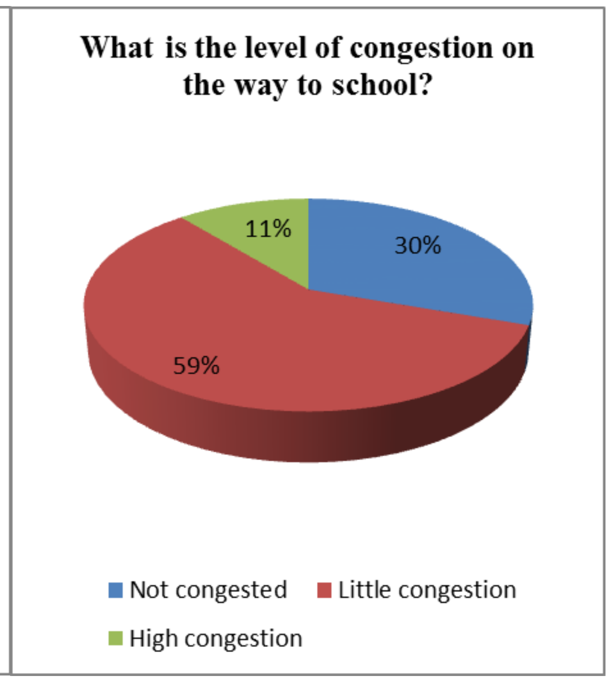
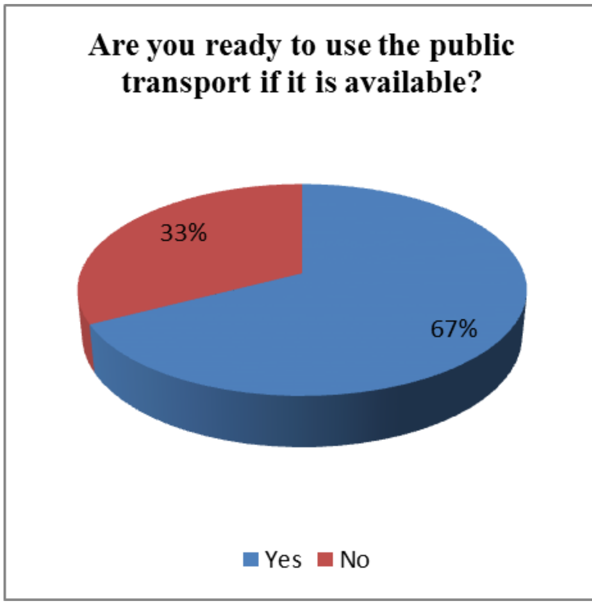



Figure 4.34: Level of congestion on the way to school

From Figures 4.32 and 4.33, the average distance from home to school is 3.30 km, and the average time required to arrive to the school is 12 min.



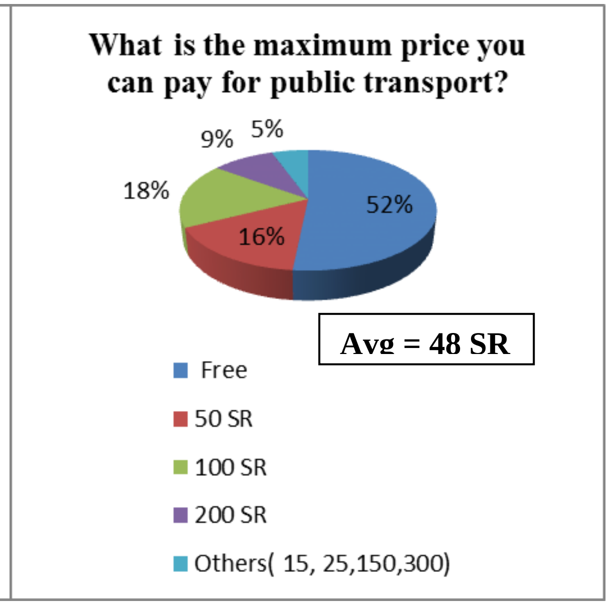
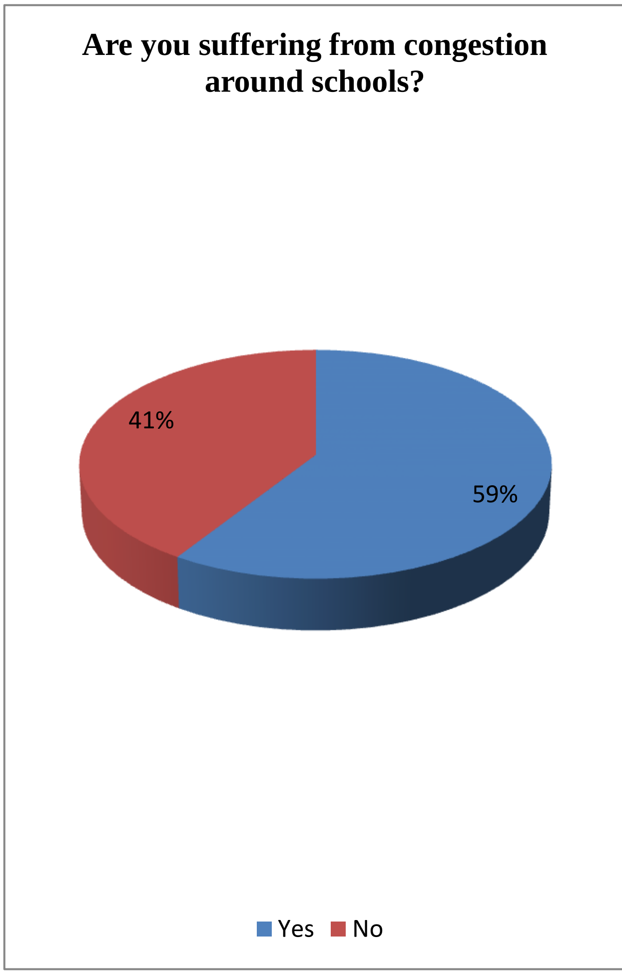




**Figure 4.35: Willingness to use public transport**

**Figure 4.36: The maximum price for public transport**

From Figures 4.35 and 4.36, 67% of the students of primary schools are ready to use public transportation, and 52% of them prefer this service to be free.



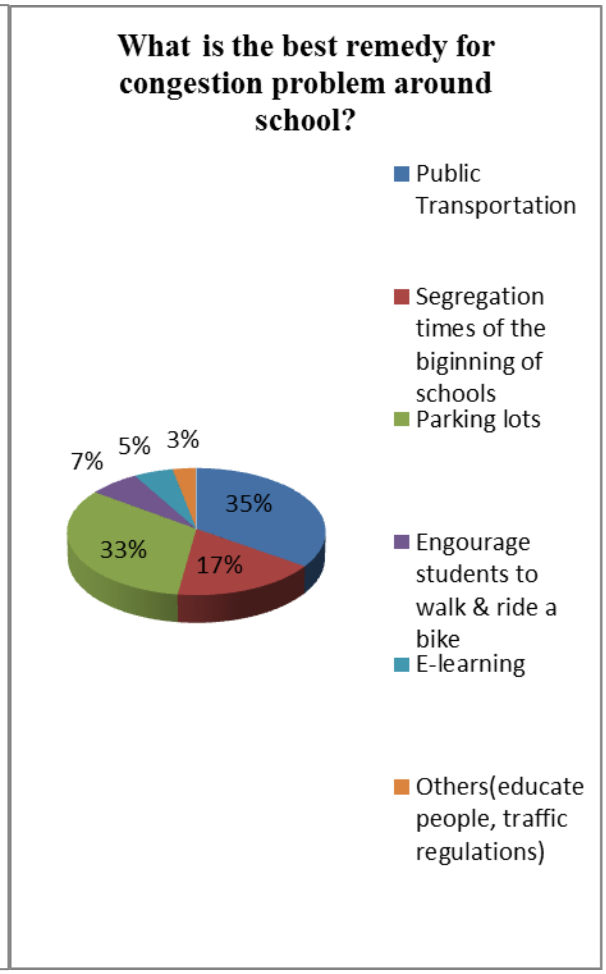




**Figure 4.37: Suffering from congestion**

**Figure 4.38: Best remedies to solve congestion problem**

According to the parents of students of primary schools, the best remedies to solve the congestion problem are providing the schools with more parking lots, segregation times of the beginning of schools, and public transportation, as shown in Figure 4.38.

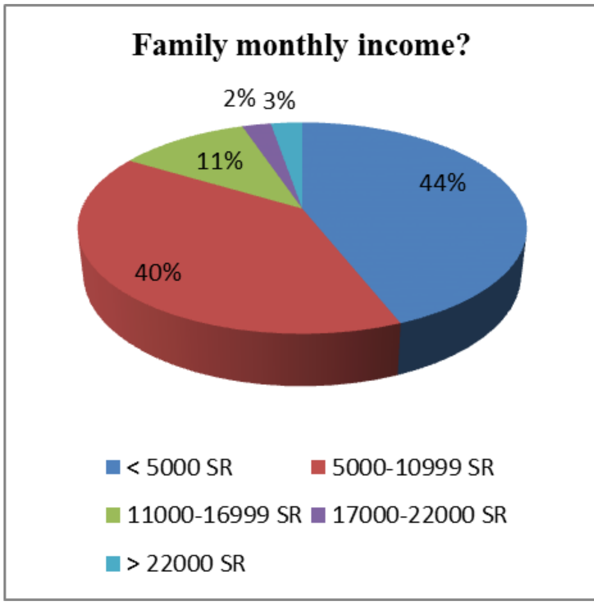



**Figure 4.39: Family monthly income**

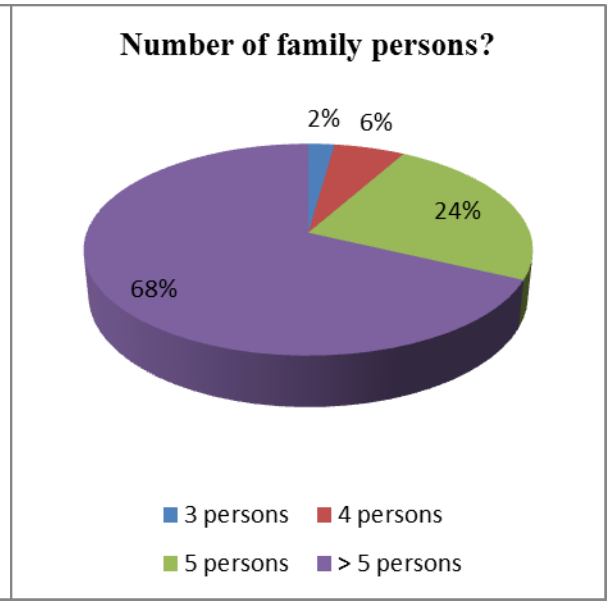



**Figure 4.40: Number of family persons**

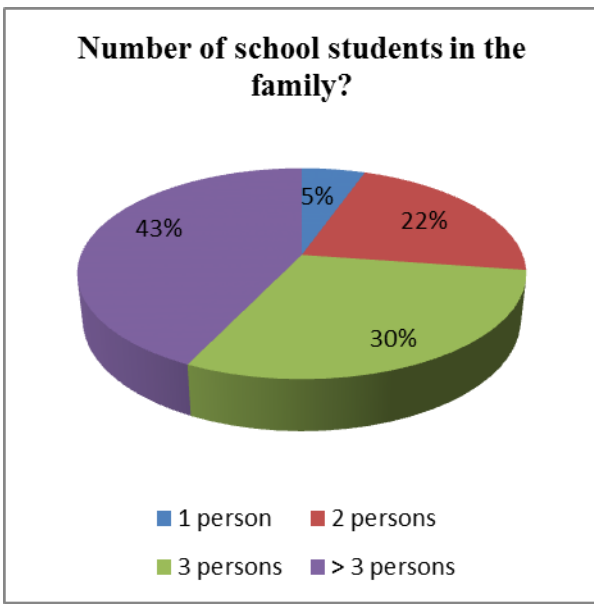



**Figure 4.41: Number of students in the family**

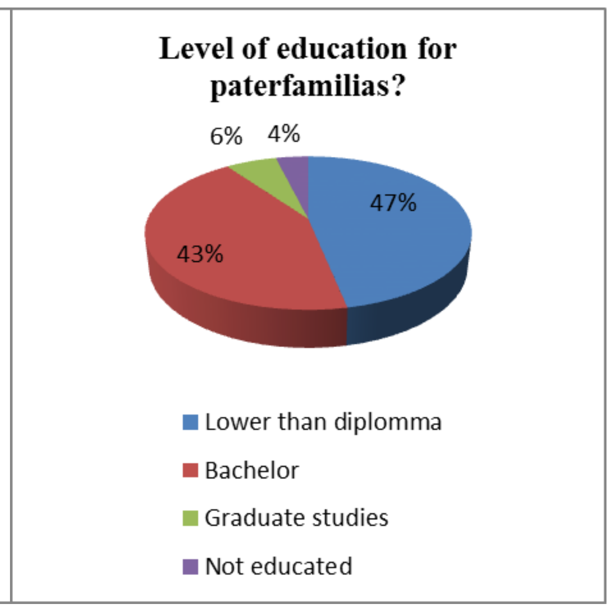



**Figure 4.42: Level of education for paterfamilias**

The weighted average for the family monthly income for students of primary schools is 8000 SR as shown in Figure 4.39.

### 4.3.4 All Levels

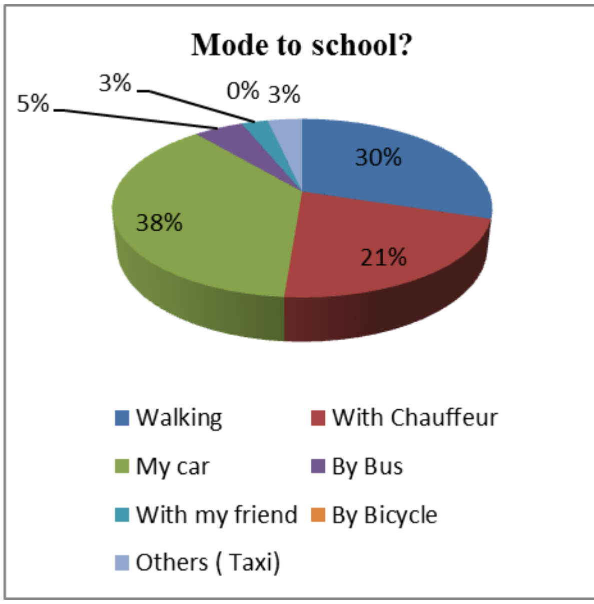



Figure 4.43: Mode to school

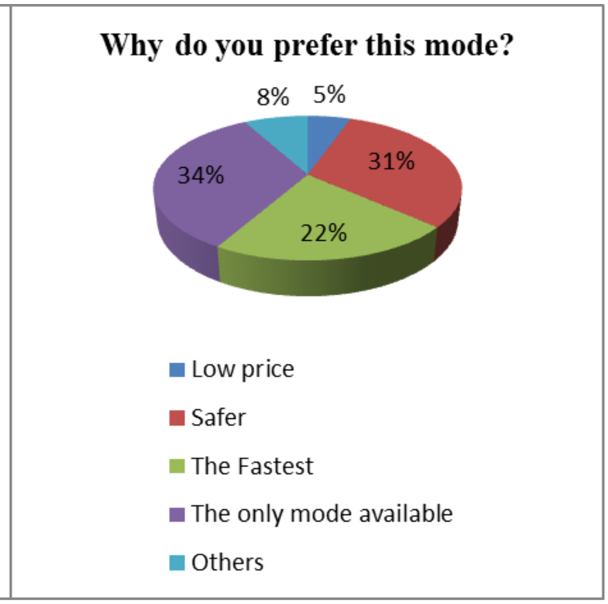



Figure 4.44: The reason for choosing this mode

From Figure 4.43, it is clear that 59% of the students of all schools are coming to the schools by passenger cars.

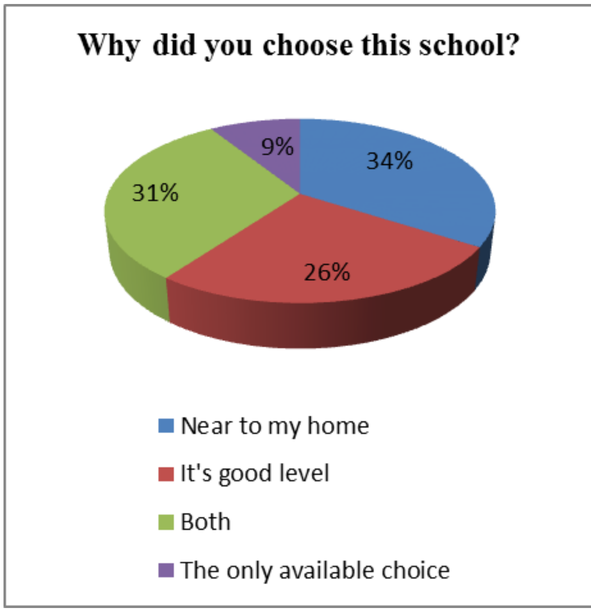



**Figure 4.45: The reason for choosing this school**

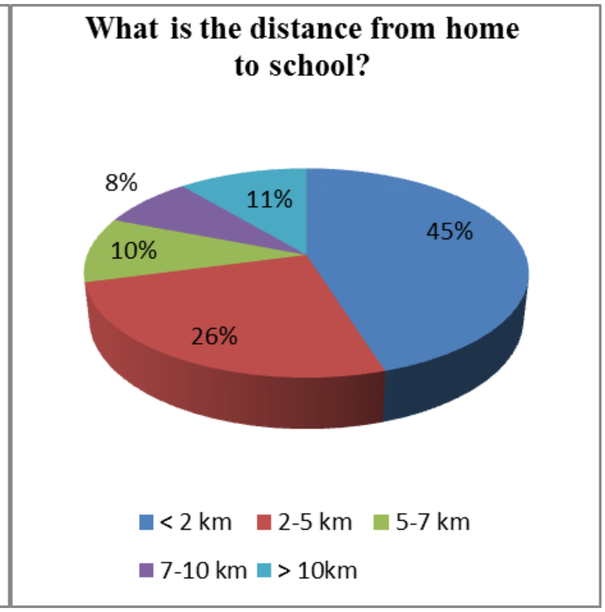



**Figure 4.46: Distance from home to school**

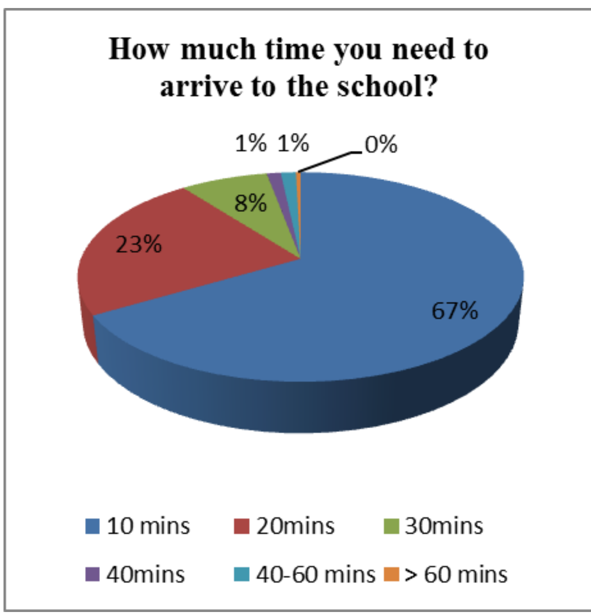



**Figure 4.47: Time required to arrive to the school**

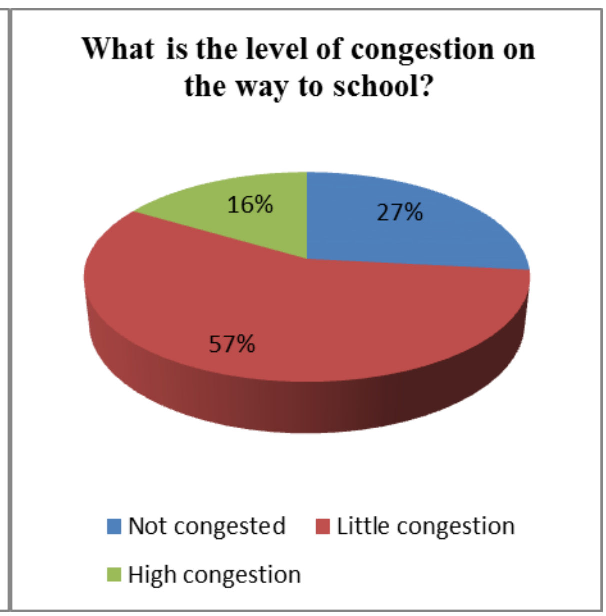
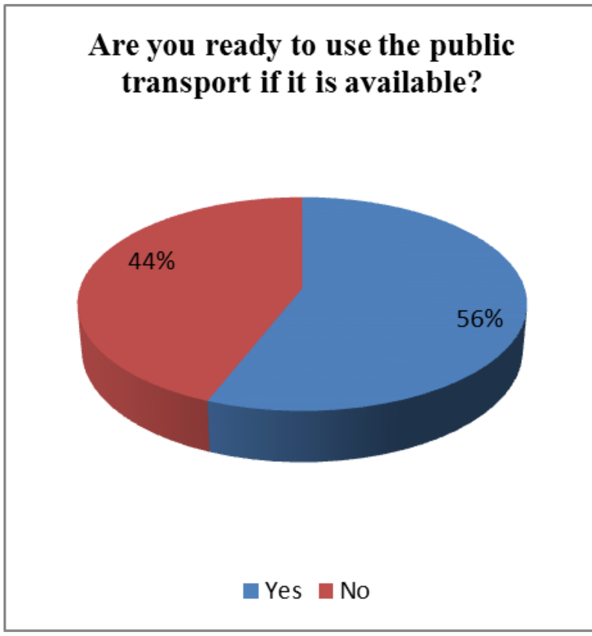



**Figure 4.48: Level of congestion on the way to school**

From Figures 4.46 and 4.47, the average distance from home to school is 4.00 km, and the average time required to arrive to the school is 14 min.



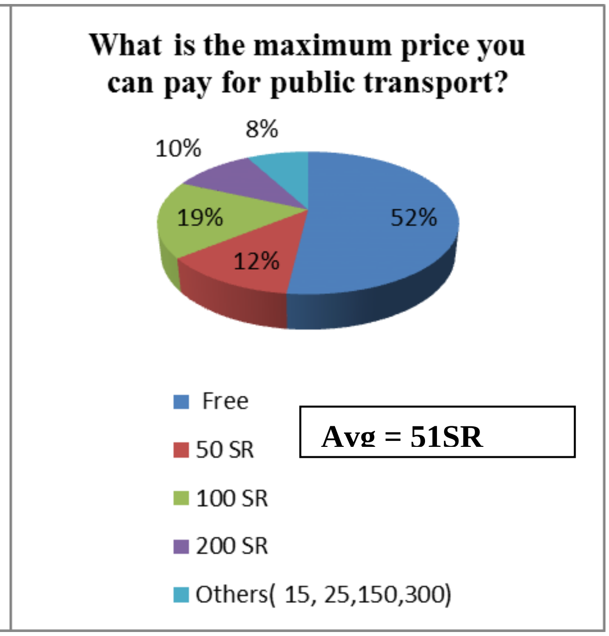




**Figure 4.49: Willingness to use public transport**

**Figure 4.50: The maximum price for public transport**

From Figures 4.49 and 4.50, 67% of all students are ready to use public transportation, and 52% of them prefer this service to be free.

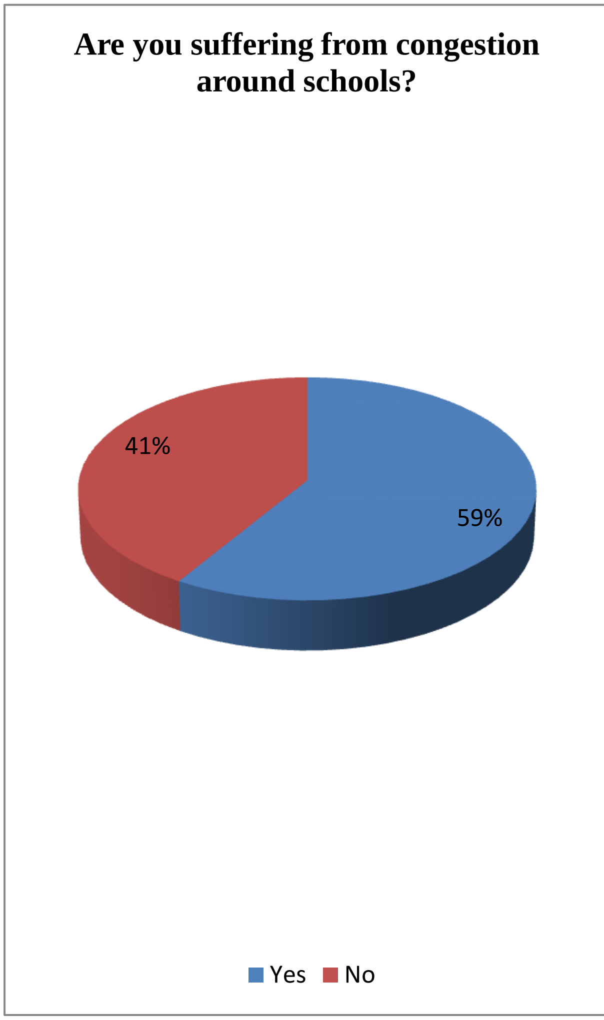



Figure 4.51: Suffering from congestion

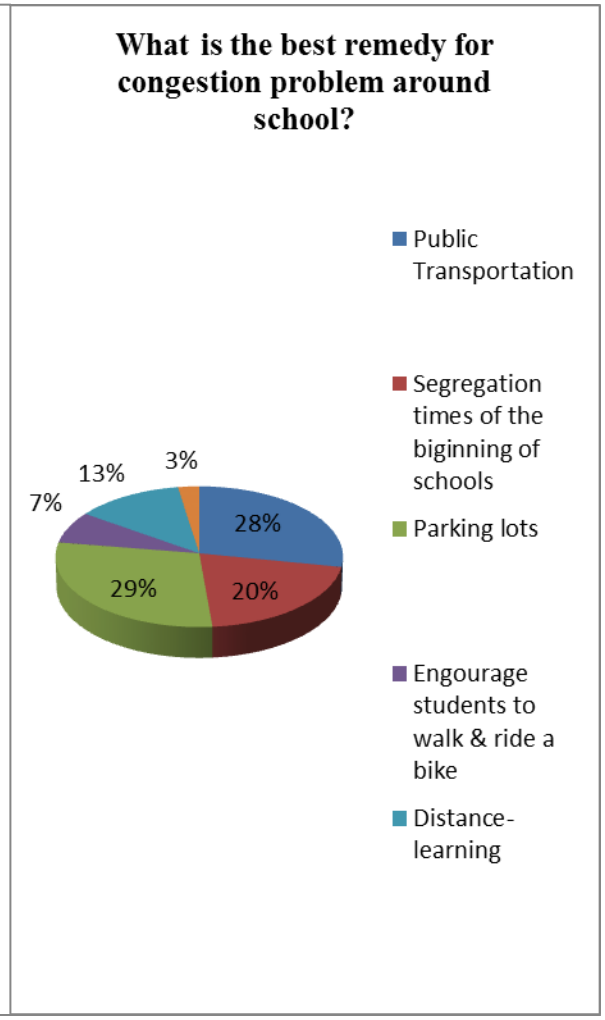
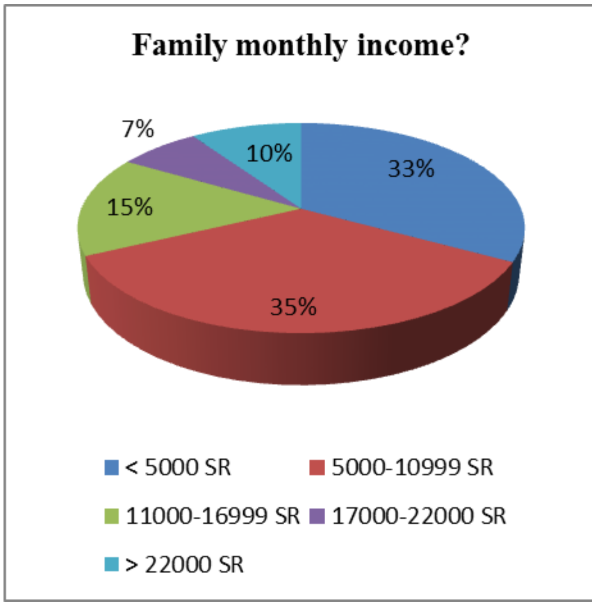



Figure 4.52: Best remedies to solve congestion problem

According to the parents and students, the best remedies to solve the congestion problem are providing the schools with more parking lots, segregation times of the beginning of schools, and public transportation, as shown in Figure 4.52.



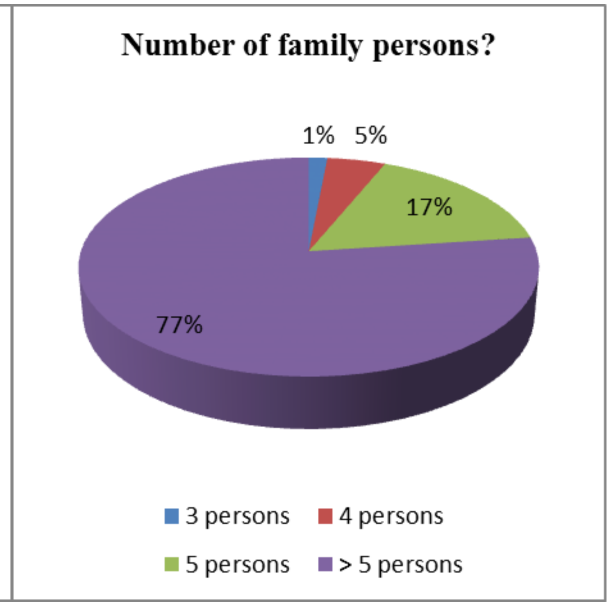
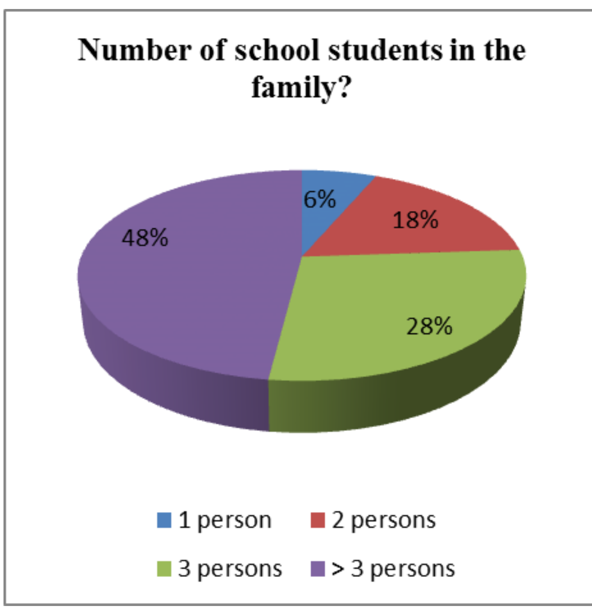




**Figure 4.53: Family monthly income**

**Figure 4.54: Number of family persons**



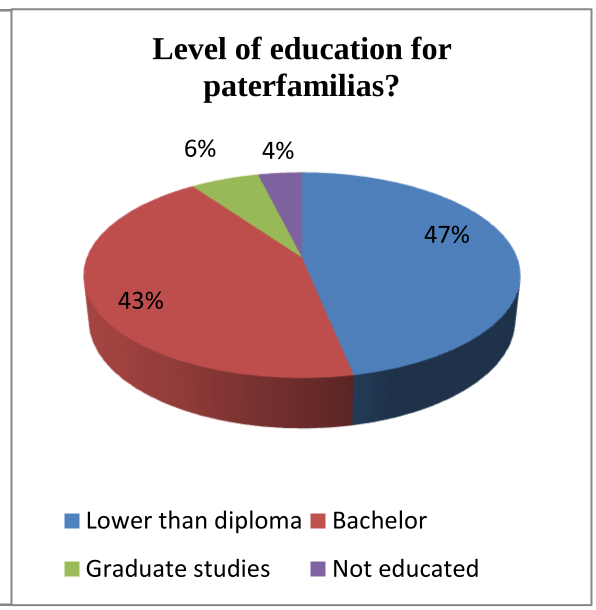




**Figure 4.55: Number of students in the family**

**Figure 4.56: Level of education for paterfamilias**

The weighted average for the family monthly income for all students is 10000 SR as shown in Figure 4.53.

## 4.4 Summary of Results

From the previous discussion and charts, it is very obvious that although nearly 60% of the students are suffering from congestion around schools, still more than 55% of the students are still coming to schools by passenger cars. On average, 56% of all students are ready to use public transportation if it is free service. The average time that is required from all the students of all levels to arrive to the school is 14 min. Nearly 28% of the respondents suggested that enhancing public transportation is the best remedy to overcome the congestion problem around schools. Another suggestion which was presented by 29% of the respondents is providing the schools with enough area for parking lots. The remaining respondents suggested segregation of school times at the beginning of the schools, encourage students to walk, strict enforcement of traffic regulations, and application of distance learning. Correlation matrices were developed to show the relationship between the number of attracted and parked vehicles and the continuous variables of the questionnaire, such as distance to school, time to school, monthly family income, number of family members, and the number of students in the family. The matrices are shown in Tables 4.5 to 4.8.

**Table 4.5: Correlation with the new variables for secondary schools**

| | *Parked* | *Total Attracted* | *Distance to home* | *Time to school* | *Family income* | *Family members* | *Students in family* |
|---|---|---|---|---|---|---|---|
| Parked | 1.00 | | | | | | |
| Total Attracted | 0.80 | 1.00 | | | | | |
| Distance to home | -0.44 | -0.52 | 1.00 | | | | |
| Time to school | -0.43 | -0.35 | 0.74 | 1.00 | | | |
| Family income | 0.45 | -0.13 | 0.24 | -0.20 | 1.00 | | |
| Family members | 0.92 | 0.51 | -0.23 | -0.40 | 0.76 | 1.00 | |
| Students in family | 0.76 | 0.61 | -0.57 | -0.60 | 0.35 | 0.71 | 1.00 |

**Table 4.6: Correlation with the new variables for intermediary schools**

| | *Parked* | *Total Attracted* | *Distance to school* | *Time to school* | *Family income* | *Family members* | *Students in family* |
|---|---|---|---|---|---|---|---|
| Parked | 1.00 | | | | | | |
| Total Attracted | 0.72 | 1.00 | | | | | |
| Distance to school | 0.57 | 0.61 | 1.00 | | | | |
| Time to school | 0.36 | 0.01 | 0.52 | 1.00 | | | |
| Family income | 0.18 | 0.26 | 0.22 | -0.03 | 1.00 | | |
| Family members | -0.67 | -0.32 | 0.18 | -0.17 | 0.10 | 1.00 | |
| Students in family | -0.67 | -0.32 | 0.18 | -0.17 | 0.10 | 1.00 | 1.00 |

**Table 4.7: Correlation with the new variables for primary schools**

| | *Parked* | *Total Attracted* | *Distance to school* | *Time to school* | *Family income* | *Family members* | *Students in family* |
|---|---|---|---|---|---|---|---|
| Parked | 1.00 | | | | | | |
| Total Attracted | 0.92 | 1.00 | | | | | |
| Distance to home | 0.14 | 0.48 | 1.00 | | | | |
| Time to school | -0.04 | 0.30 | 0.80 | 1.00 | | | |
| Family income | 0.26 | 0.51 | 0.86 | 0.39 | 1.00 | | |
| Family members | 0.88 | 0.77 | -0.14 | -0.05 | -0.14 | 1.00 | |
| Students in family | 0.69 | 0.77 | 0.21 | 0.19 | 0.23 | 0.79 | 1.00 |

**Table 4.8: Correlation with the new variables for all levels schools**

| | *Parked* | *Total Attracted* | *Distance to home* | *Time to school* | *Family income* | *Family members* | *Students in family* |
|---|---|---|---|---|---|---|---|
| Parked | 1.00 | | | | | | |
| Total Attracted | 0.39 | 1.00 | | | | | |
| Distance to home | 0.44 | 0.02 | 1.00 | | | | |
| Time to school | 0.50 | 0.13 | 0.82 | 1.00 | | | |
| Family income | 0.50 | 0.25 | 0.53 | 0.44 | 1.00 | | |
| Family members | 0.59 | 0.23 | 0.21 | 0.18 | 0.33 | 1.00 | |
| Students in family | 0.07 | 0.26 | -0.27 | -0.19 | 0.10 | 0.66 | 1.00 |

From the correlation matrices above, there are strong relationships between the number of attracted and parked vehicles and the number of family members and number of students in the family when the school level is secondary or primary since the correlation coefficients are very high. For intermediary schools, there is a strong relationship between the number of attracted and parked vehicles and the distance to school. It is recommended to use these new variables which are significant in modeling of trip attraction and parking generation.

# CHAPTER 5

# CASE STUDY

## 5.1 Introduction

Optimization of the overall network during the peak hour of the school has good effect in reducing congestion around schools. This chapter concentrates on the effect of optimizing an intersection near a primary school and demonstrates that a straightforward engineering solution can have positive impacts on congestion around schools. This study was done at the intersection of Prince Miqrin Street and 22nd Street near Al-Seddeeq primary school in Al-Aqrabiyya. The gate of the school is located on the west leg of the intersection as shown in Figure 5.1 below.

From the field visits of the school, it was obvious that during the AM peak hour of the school, a lot of delay happened for most of the vehicles using the intersection since 45 sec was allocated as green time for eastbound vehicles (west leg) and only 60 sec of the green time was for the other bounds. A team of 4 persons counted the directional number of vehicles using the intersection from 6:00 AM to 7:30 AM.

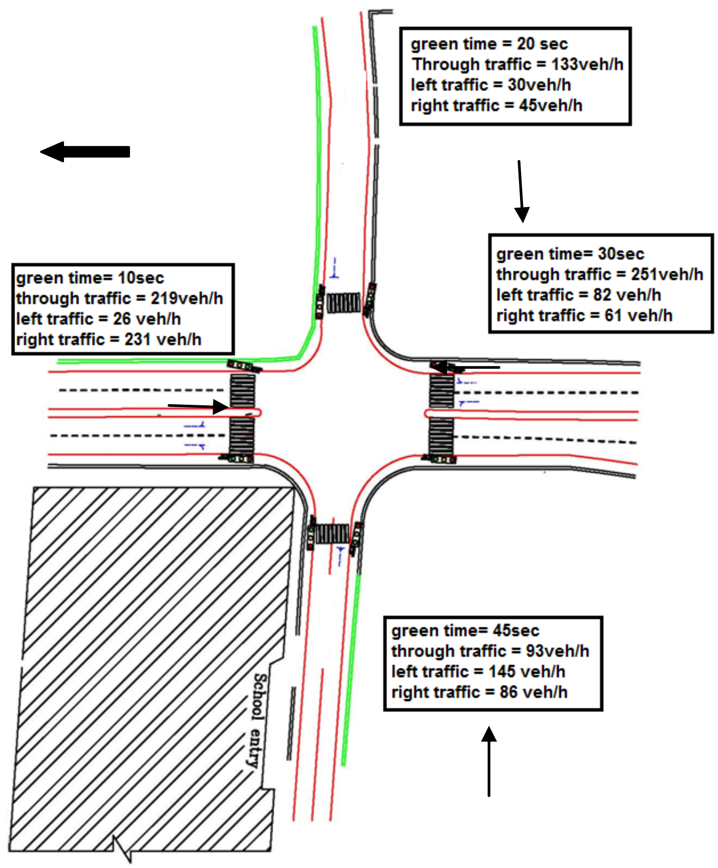



**Figure 5.1: Intersection layout**

## 5.2 Data Collection

The number of vehicles with their directions was collected using the mechanical counters from 6:00 AM to 7:30 AM. The cycle length for the intersection was 125 sec. 45 sec of green was for eastbound, 10 sec for southbound , 20 sec for westbound, and 30 sec for the northbound. The number of vehicles for each 15 minutes is presented in Tables 5.1 to 5.4.

**Table 5.1: Traffic counts for eastbound**

| Starting time | Eastbound | | | Total vehicles |
|---|---|---|---|---|
| | P | | | |
| | R | S | L | |
| 6:00-6:15 AM | 7 | 4 | 9 | 20 |
| 6:15-6:30 AM | 13 | 14 | 20 | 47 |
| 6:30-6:45 AM | 17 | 24 | 49 | 90 |
| 6:45-7:00 AM | 23 | 34 | 43 | 100 |
| 7:00-7:15 AM | 33 | 21 | 33 | 87 |
| 7:15-7:30 AM | 20 | 26 | 17 | 63 |
| Total | 113 | 123 | 171 | 407 |

**Table 5.2: Traffic counts for southbound**

| Starting time | Southbound | | | Total vehicles |
|---|---|---|---|---|
| | P | | | |
| | R | S | L | |
| 6:00-6:15 AM | 15 | 6 | 2 | 23 |
| 6:15-6:30 AM | 36 | 29 | 5 | 70 |
| 6:30-6:45 AM | 79 | 64 | 5 | 148 |
| 6:45-7:00 AM | 61 | 77 | 8 | 146 |
| 7:00-7:15 AM | 55 | 49 | 8 | 112 |
| 7:15-7:30 AM | 23 | 25 | 5 | 53 |
| Total | 269 | 250 | 33 | 552 |

**Table 5.3: Traffic counts for westbound**

| Starting time | Westbound | | | Total vehicles |
|---|---|---|---|---|
| | P | | | |
| | R | S | L | |
| 6:00-6:15 AM | 5 | 11 | 7 | 23 |
| 6:15-6:30 AM | 10 | 14 | 5 | 29 |
| 6:30-6:45 AM | 10 | 35 | 5 | 50 |
| 6:45-7:00 AM | 16 | 38 | 12 | 66 |
| 7:00-7:15 AM | 9 | 46 | 8 | 63 |
| 7:15-7:30 AM | 7 | 26 | 13 | 46 |
| Total | 57 | 170 | 50 | 277 |

**Table 5.4: Traffic counts for northbound**

| Starting time | Northbound | | | Total vehicles |
|---|---|---|---|---|
| | P | | | |
| | R | S | L | |
| 6:00-6:15 AM | 7 | 19 | 5 | 31 |
| 6:15-6:30 AM | 15 | 51 | 14 | 80 |
| 6:30-6:45 AM | 15 | 73 | 24 | 112 |
| 6:45-7:00 AM | 15 | 75 | 25 | 115 |
| 7:00-7:15 AM | 16 | 52 | 19 | 87 |
| 7:15-7:30 AM | 8 | 37 | 17 | 62 |
| Total | 76 | 307 | 104 | 487 |

The peak hour was from 6:15-7:15 AM since the maximum volume came at this hour.

## 5.3 Simulation and Optimization

TRANSYT-7F was used to simulate the existing conditions and then used to optimize the best conditions in which the delay time and number of stops were minimal. Table 5.5 shows the performance measures for the existing conditions while Table 5.6 shows the same measures for the optimal conditions. The objective function was to minimize the fuel consumption.

**Table 5.5: Simulation of the existing conditions**

| Cycle Length = 125 sec<br>Green time for southbound = 10sec<br>Green time for westbound = 20 sec<br>Green time for northbound = 30 sec<br>Green time for eastbound = 45 sec | | |
|---|---|---|
| **Performance Measures** | **Units** | **System Totals** |
| Total Travel Time | veh-km/hr | 144 |
| Total Uniform Delay | veh-hr/hr | 47 |
| Total Random Delay | veh-hr/hr | 87 |
| Total Delay | veh-hr/hr | 134 |
| Average Delay | sec/veh | 282.8 |
| Passenger Delay | pax-hr/hr | 161 |
| Uniform Stops | veh/hr | 1596 |
| Random Stops | veh/hr | 1228 |
| Total Stops | veh/hr | 2824 |
| Degree of Sat > 1 | # of links | 2 |
| Queue Spillback | # of links | 0 |
| Time Jammed | % | 0 |
| System Speed | km/hr | 4.8 |
| Fuel Consumption | lit/hr | 502 |
| Operating Cost | $/hr | 716 |
| Performance Index | DI | 133.10 |

**Table 5.6: Simulation of the optimal conditions**

| Cycle Length = 100 sec<br>Green time for southbound = 24sec<br>Green time for westbound = 15 sec<br>Green time for northbound = 13 sec<br>Green time for eastbound = 28 sec | | |
|---|---|---|
| **Performance Measures** | **Units** | **System Totals** |
| Total Travel Time | veh-km/hr | 67 |
| Total Uniform Delay | veh-hr/hr | 22 |
| Total Random Delay | veh-hr/hr | 36 |
| Total Delay | veh-hr/hr | 58 |
| Average Delay | sec/veh | 121.9 |
| Passenger Delay | pax-hr/hr | 69 |
| Uniform Stops | Veh/hr | 1930 |
| Random Stops | Veh/hr | 956 |
| Total Stops | Veh/hr | 2886 |
| Degree of Sat > 1 | # of links | 3 |
| Queue Spillback | # of links | 0 |
| Time Jammed | % | 0 |
| System Speed | km/hr | 10.2 |
| Fuel Consumption | lit/hr | 306 |
| Operating Cost | $/hr | 544 |
| Performance Index | DI | 77.90 |

## 5.4 Summary

By comparing the performance measures for the existing conditions and optimal conditions, it is clear that the average delay for each vehicle was reduced by more than 50%, which led to the reduction in fuel consumption and operating cost and increased the system speed from 4.8 km/hr to 10.2 km/hr. Furthermore, it is clear that the performance index represented by the excess fuel consumption was reduced dramatically from 133.1 to 77.90, which means that some simple engineering remedies can make a lot of positive impacts. The existing green time for the eastbound leg is 45 sec but the optimized one is 28 sec. The designer of the signal timing thought that the existence of the school on the eastbound leg will increase the traffic volume on that leg, but in actual conditions most of the traffic in the AM peak hour was for north and south bounds in which the green time for both of them was 40 sec, resulting in increase in the delay and fuel consumption.

# CHAPTER 6

# CONCLUSIONS AND RECOMMENDATIONS

The ultimate objective of this study was to evaluate the traffic impact of schools and this was accomplished in three parts which are: modeling of trip and parking generation, assessing the acceptance by students and their parents of some of the remedies for mitigating congestion around schools through questionnaire survey, and an engineering exercise to show and prove that a simple straightforward engineering solution can have a considerable positive impact. From the analyses and results for these three parts, it can be concluded that:

- It is obvious that the worst models in predicting the number of attracted vehicles to schools are Riyadh city manual models since in most cases these models overestimated the number of attracted vehicles, especially when the variable used is the lot or floor area.
- ITE and Dubai trip generation rates predicted the number of attracted vehicles much better than that predicted by Riyadh city rates.
- The best variables in predicting the number of attracted and parked vehicles were the number of students and number of employees. Tables 6.1 to 6.2 present the best models for trip and parking generation for each level of schools.

**Table 6.1: Best models for trip attraction of each level of schools**

| School level | Best models **(trip attraction)** | $R^2$ | *Planning model |
|---|---|---|---|
| Secondary | Attracted vehicles = 4.84 * Number of employees | 0.86 | Attracted vehicles = 36.47 * Floor area |
| Intermediary | Attracted vehicles = 0.56 * Number of students | 0.87 | Attracted vehicles = 57 * Floor area |
| Primary | Attracted vehicles = 5.40 * Number of employees | 0.85 | Attracted vehicles = 61 * Floor area |

**Can be used in planning stage when detail data about schools is not available.*

**Table 6.2: Best models for parking generation of each level of schools**

| School level | Best models **(parking generation)** | $R^2$ | * Planning model |
|---|---|---|---|
| Secondary | Parked vehicles = 1.97 * Number of employees | 0.82 | Parked vehicles = 14.76 * Floor area |
| Intermediary | Parked vehicles = 0.08 * Number of students | 0.87 | Parked vehicles = 8.5 * Floor area |
| Primary | Parked vehicles = 0.95 * Number of employees | 0.89 | Parked vehicles = 10.5 * Floor area |

**Can be used in planning stage when detail data about schools is not available.*

- In planning stage in which the information is scarce, using the floor area is adequate but with less accuracy.
- The worst variable in predicting the number of attracted and parked vehicles was the lot area.
- It is better to deal with each level of schools separately since the models that resulted from the analysis of pooled schools together are statistically less significant from the others.

- It is suggested to use the developed models rather than the local models or international models in the study area.
- In other areas of the Kingdom, the planner has an option to use the developed models or the ITE models since there is no big difference between the predicted values using both models.
- From the questionnaire analysis, it is obvious that 60% of overall students are suffering from congestion around schools but still 59% of them are coming to schools by passenger cars.
- 33% of overall students are ready to use the public transportation if it is free service and 27% are ready to pay an average of 51 SR.
- 30% of the people suggested public transportation as a solution for congestion, 28% suggested providing more parking lots, 18% suggested segregation time as a remedy, 12% suggested distance learning, and others suggested encouraging students to walk and educate people.
- As shown in the case study, some simple engineering improvement such as optimization of signal timing can make a big difference in reducing congestion.

# CHAPTER 7

# REFERENCES


1. Organisation for Economic Co-operation and Development, *Managing Urban Traffic Congestion*, Paris, 2007.

2. General Traffic Directorate, *Annual Traffic Report* (1971-2010).

3. The General Administration of Traffic, Saudi Arabia, *Annual Statistical Report*, 2011.

4. Institute of Transportation Engineers, *Trip Generation*, 8$^{th}$ edition, 2008.

5. Institute of Transportation Engineers, *Trip Generation*, 6$^{th}$ edition, 1997.

6. The Ministry of Municipal and Rural Affairs, Saudi Arabia, *Trip Generation Manual for Riyadh City*, 2009.

7. Roads and Transport Authority, G.o.D., *Dubai Trip Generation and Parking Rates*, 2013.

8. La Vigne, N.G., *Traffic Congestion Around Schools,* US Department of Justice, Office of Community Oriented Policing Services, 2007.

9. Braza, M., W. Shoemaker, and A. Seeley, "Neighborhood design and rates of walking and biking to elementary school in 34 California communities", *American Journal of Health Promotion*, Vol. 19, No. 2, 2004, pp. 128-136.

10. Downs, A., *Still Stuck in Traffic: Coping with Peak-hour Traffic Congestion*, Brookings Institution Press, 2004.

11. Black, C., A. Collins, and M. Snell, "Encouraging walking: the case of journey-to-school trips in compact urban areas", *Urban Studies*, Vol. 38, No. 7, 2001, pp. 1121-1141.

12. Cynecki, M.J. and R.G. Brownlee, "Planning the location and design of schools in relation to the transportation network", In *ITE 2007 Annual Meeting and Exhibit*, 2007.

13. McDonald, N.C., “Children’s mode choice for the school trip: the role of distance and school location in walking to school”, *Transportation,* Vol. 35, No. 1, 2008, pp. 23-35.

14. Slipp, P.R. and J.E. Hummer, “Trip generation rate update for public high schools”, *ITE Journal*, Vol. 66, No. 6, 1996.

15. Dean, D., T. Dean, and A. Alfridi, “City of Surrey pick-up/drop-off trip generation survey”, In *ITE 2010 Annual Meeting and Exhibit*, 2010.

16. Quiroga, C.A., “Performance measures and data requirements for congestion management systems”, *Transportation Research Part C: Emerging Technologies*, Vol. 8, No. 1, 2000, pp. 287-306.

17. Dadić, I., et al., “Measures for reducing traffic congestion in cities”, *PROMET-Traffic & Transportation*, Vol. 11, No. 1, 2012, pp. 15-19.

18. Valentine, G., “Angels and devils: moral landscapes of childhood”, *Environment and Planning D*, Vol. 14, 1996, pp. 581-600.

19. Colorado Department of Transportation, *School Zone Traffic Safety Evaluation*, Colorado, 2005.

20. Bradshaw, R., “Why do parents drive their children to school?”, *Traffic Engineering and Control*, Vol. 36, No. 1, 1995.

21. Australian Department of Transport, *Guidelines for Road Safety Around Schools*, 2007.

22. Zhao, J. and H. Zhou, “Examine the factors that affect the number of students walking and biking to school”, In *ITE 2010 Annual Meeting and Exhibit*, 2010.

23. Qualls, D.W., “Strategies for the greening of student pick-ups at school dismissal”, In *ITE 2010 Annual Meeting and Exhibit*, 2010.

24. Sarasua, W., J. Townsend, and S. Trott, “Using ITS technology to enhance after-school traffic operations: an elementary school case study”, In *Institute of Transportation Engineers (ITE) 2003 Technical Conference and Exhibit*, 2003.

25. Florida Departement of Transportation, *Impact of Parking Supply and Demand Management on Central Business District (CBD) Traffic Congestion, Transit Performance and Sustainable Land Use*, 2012.

26. McCourt, R., Institute of Transportation Engineers, *Parking Generation*, 3rd Edition, 2004.

27. *Census Report for 2010*, Saudi Arabia, 2010.

28. Foong, N., L.H. Chin, and Q.S. Hoe, "Mean squared error – a tool to evaluate the accuracy of parameter estimators in regression", *Journal of Quality Measurement and Analysis (JQMA)*, Vol. 4, No. 1, 2008, pp. 71-80.

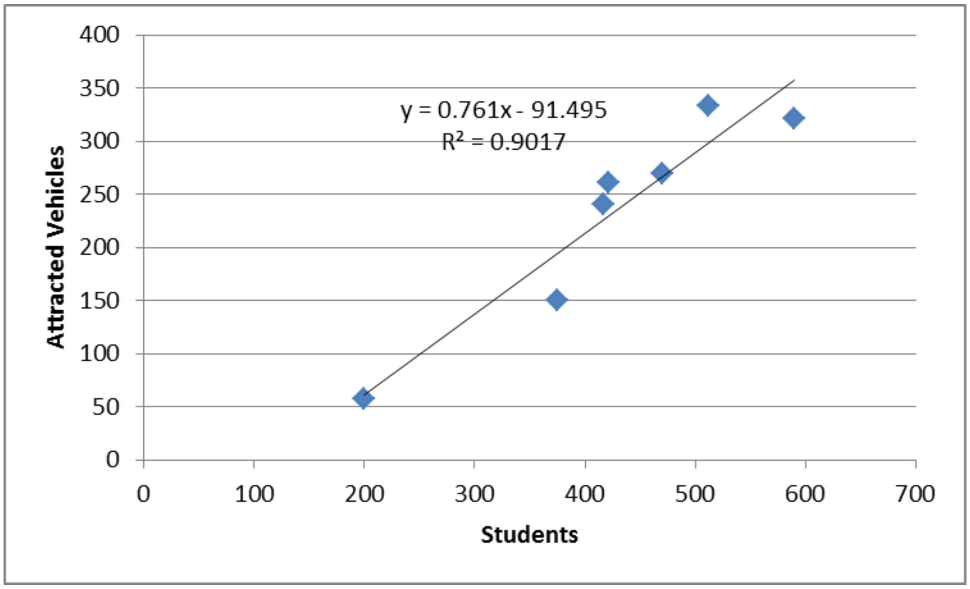
## APPENDIX A

## SAMPLE OF DATA ANALYSIS FOR TRIP ATTRACTION (INTERMEDIARY SCHOOLS)

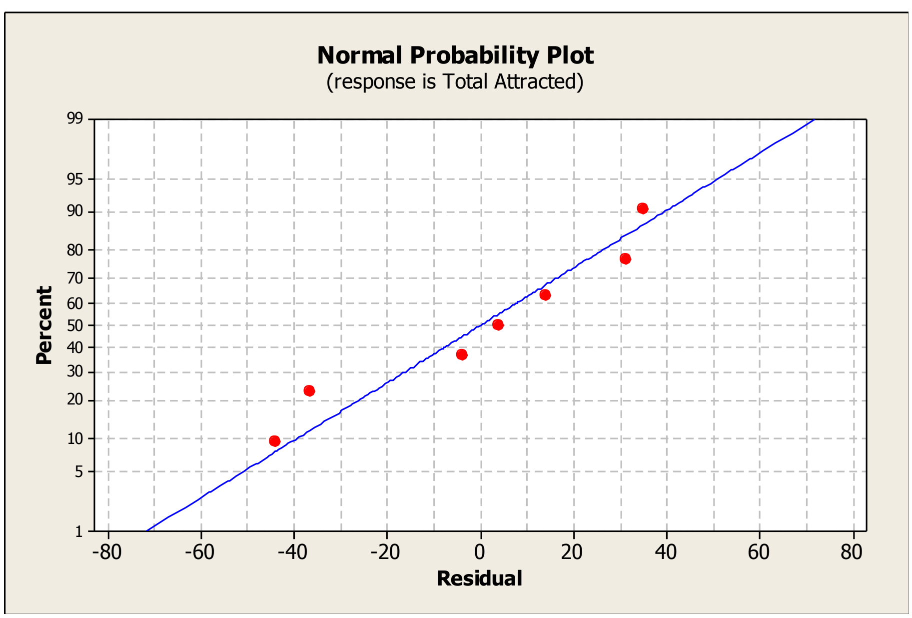
## Data analysis using seven schools only

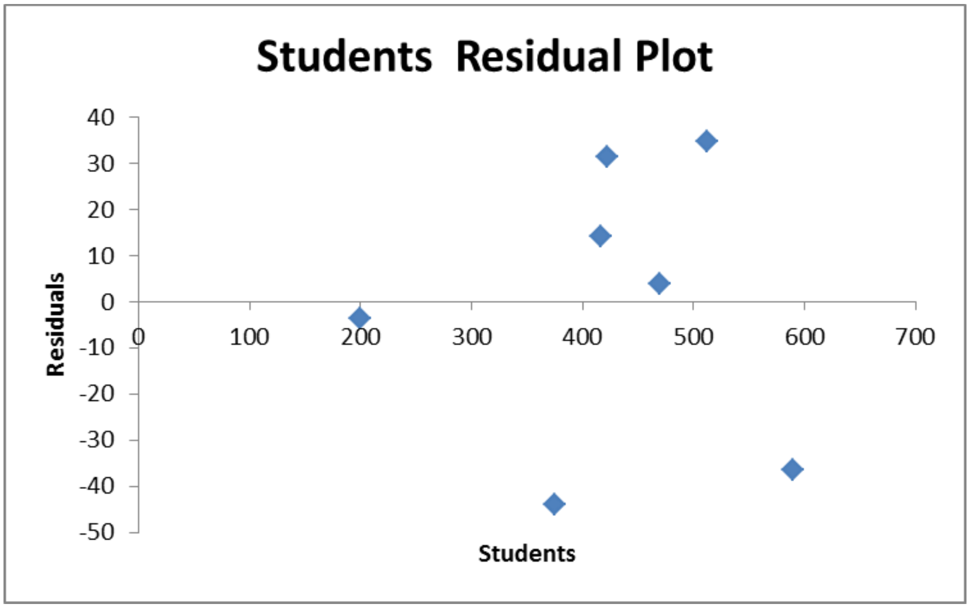
## Simple linear regression

Students




**Correlation of the number of students with the volume attracted (school level: Secondary)**






SUMMARY
OUTPUT

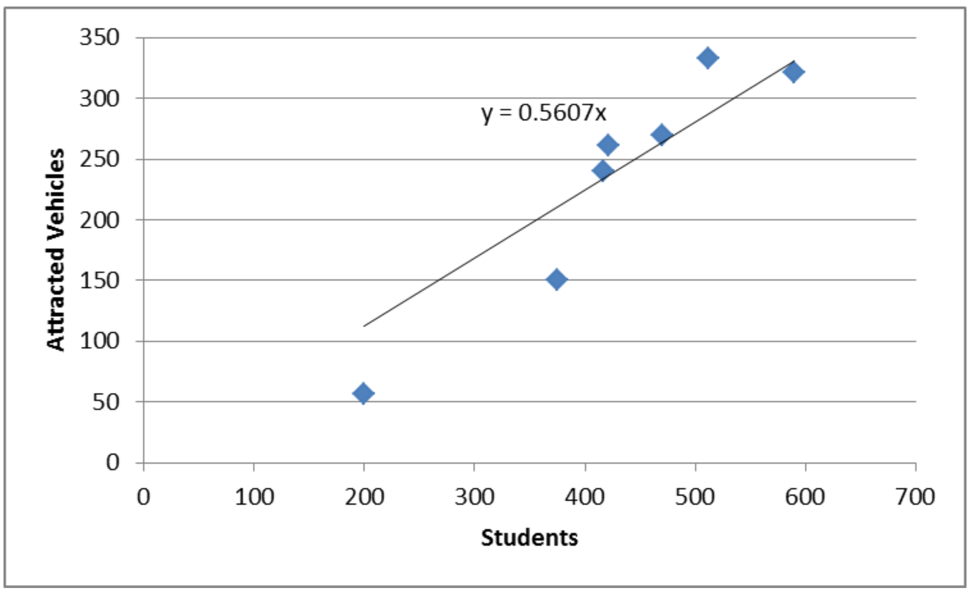
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.949563 |
| R Square | 0.901669 |
| Adjusted R Square | 0.882003 |
| Standard Error | 33.71819 |
| Observations | 7 |

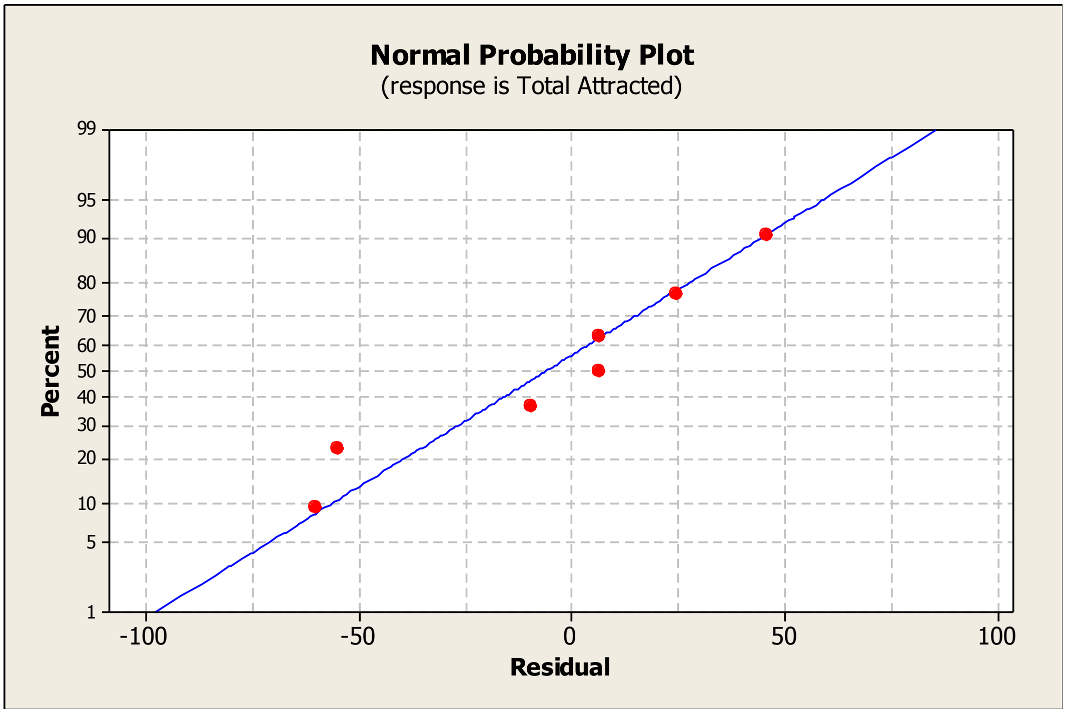
ANOVA

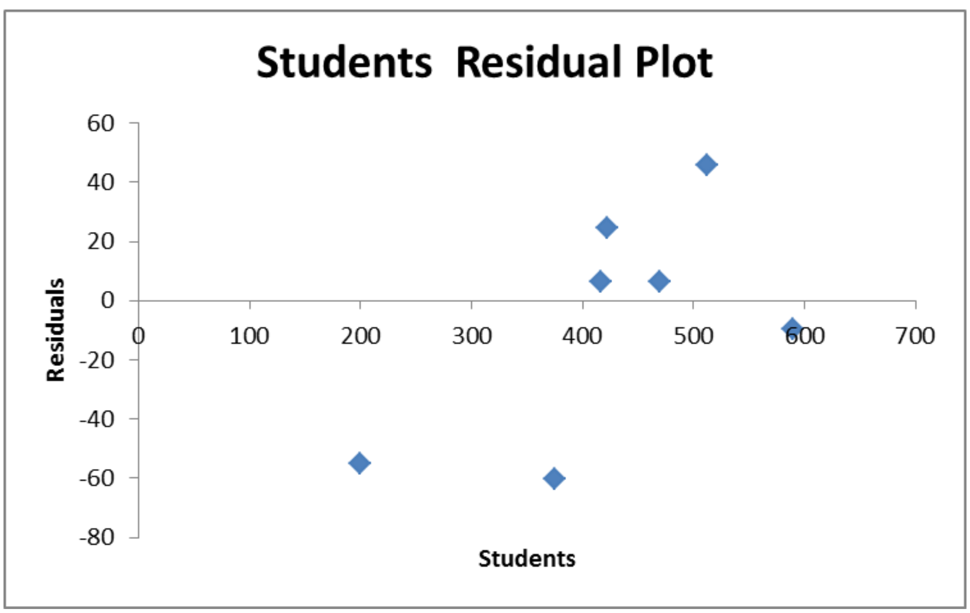
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 52126.27 | 52126.27 | 45.84881 | 0.001067818 |
| Residual | 5 | 5684.583 | 1136.917 | | |
| Total | 6 | 57810.86 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | -91.49528094 | 49.60904147 | -1.84433 | 0.124453 |
| Students | 0.761040511 | 0.112394161 | 6.771175 | 0.001068 |

**<u>Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below</u>**




Normal Probability Plot
(response is Total Attracted)
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
-100
-50
0
50
100
Residual


Students Residual Plot
Residuals
60
40
20
0
-20
-40
-60
-80
0
100
200
300
400
500
600
700
Students

SUMMARY OUTPUT

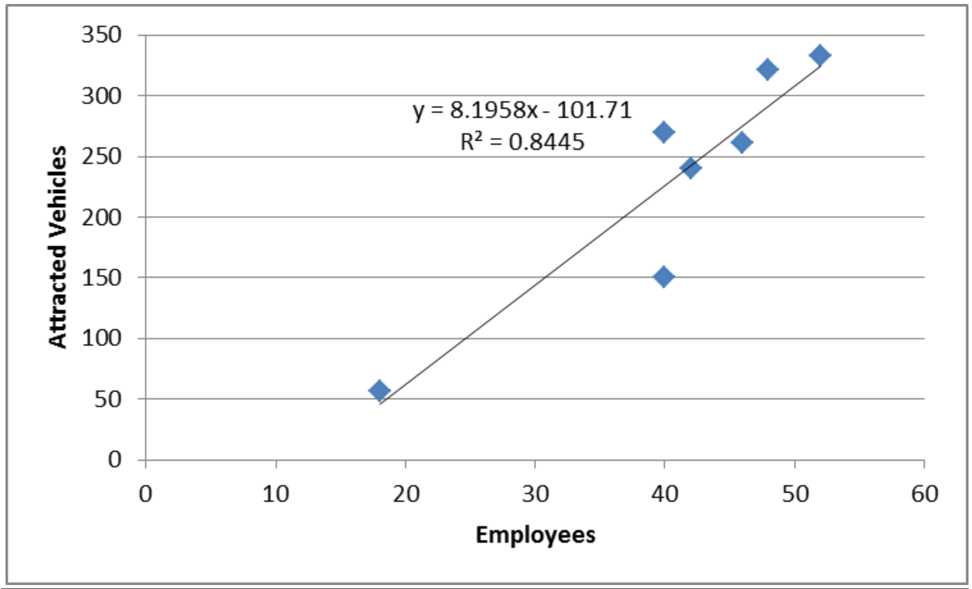
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.989044 |
| R Square | 0.978207 |
| Adjusted R Square | 0.81154 |
| Standard Error | 39.89957 |
| Observations | 7 |

ANOVA

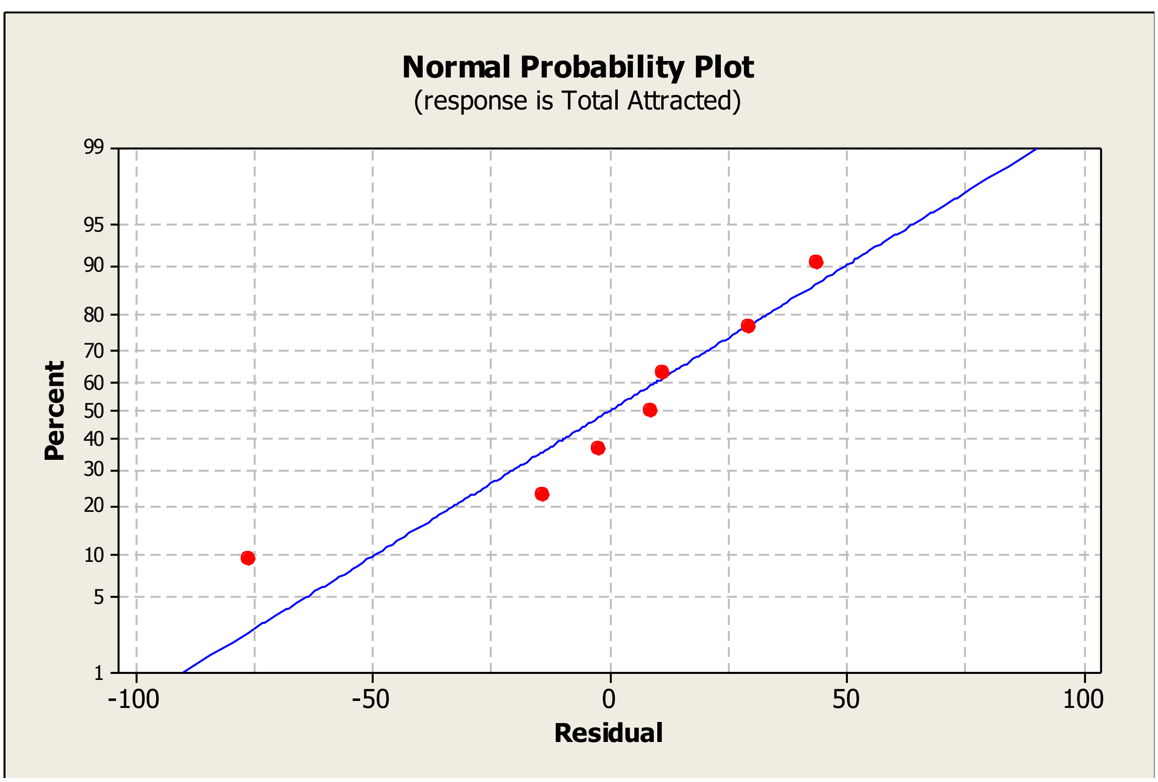
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 428748.1 | 428748.1 | 269.3183 | 1.5329E-05 |
| Residual | 6 | 9551.852 | 1591.975 | | |
| Total | 7 | 438300 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Students | 0.56070576 | 0.034166623 | 16.41092 | 3.26E-06 |

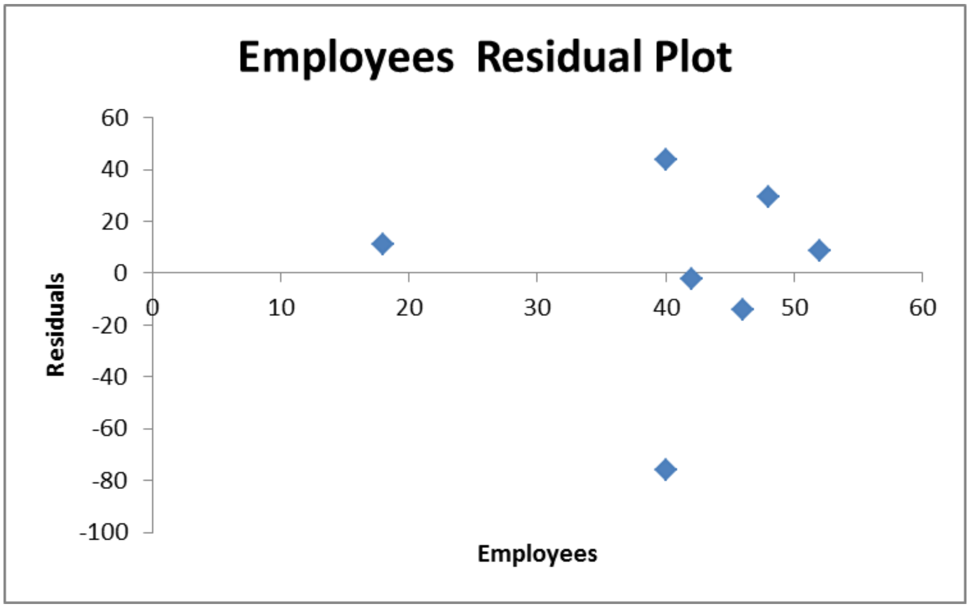
## Employees



y = 8.1958x - 101.71
R² = 0.8445
Attracted Vehicles
Employees
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60

Normal Probability Plot
(response is Total Attracted)
Percent
Residual
99
95
90
80
70
60
50
40
30
20
10
5
1
-100
-50
0
50
100




SUMMARY OUTPUT

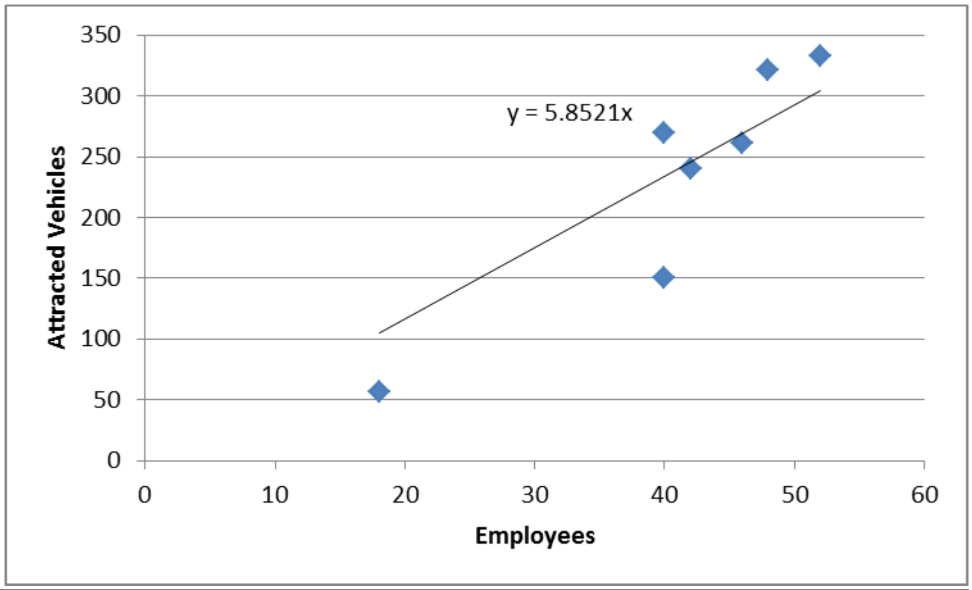
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.918985755 |
| R Square | 0.844534817 |
| Adjusted R Square | 0.813441781 |
| Standard Error | 42.39711186 |
| Observations | 7 |

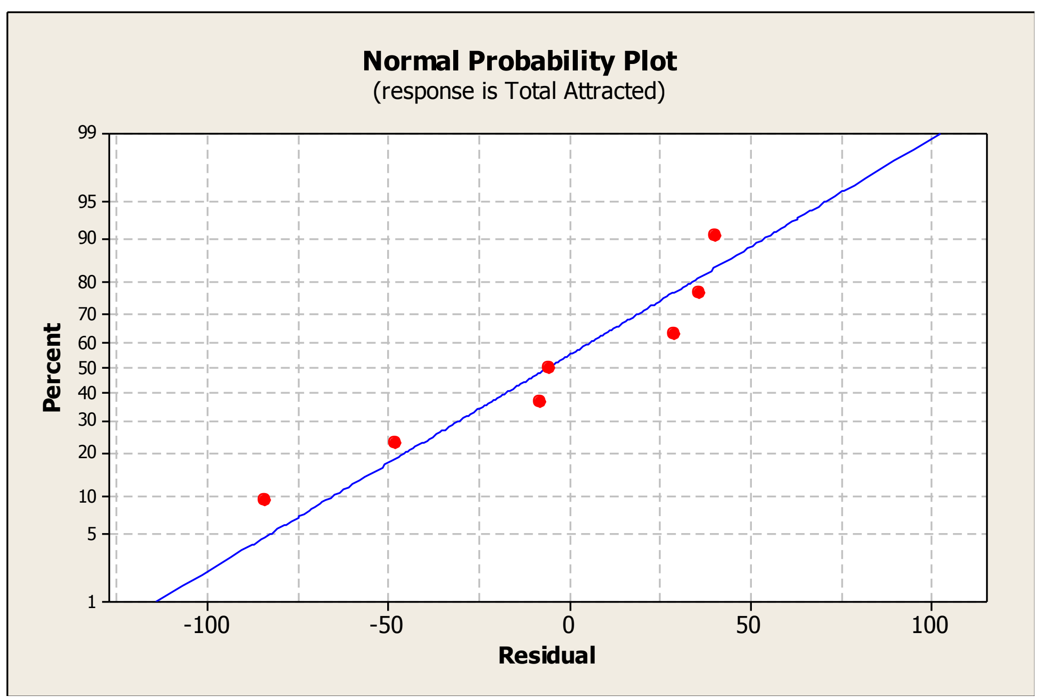
ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 48823.28 | 48823.28 | 27.16154 | 0.003433551 |
| Residual | 5 | 8987.575 | 1797.515 | | |
| Total | 6 | 57810.86 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | -101.7122642 | 66.21915051 | -1.53599 | 0.185138 |
| Employees | 8.195754717 | 1.572576356 | 5.211674 | 0.003434 |

**<u>Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below</u>**




SUMMARY OUTPUT

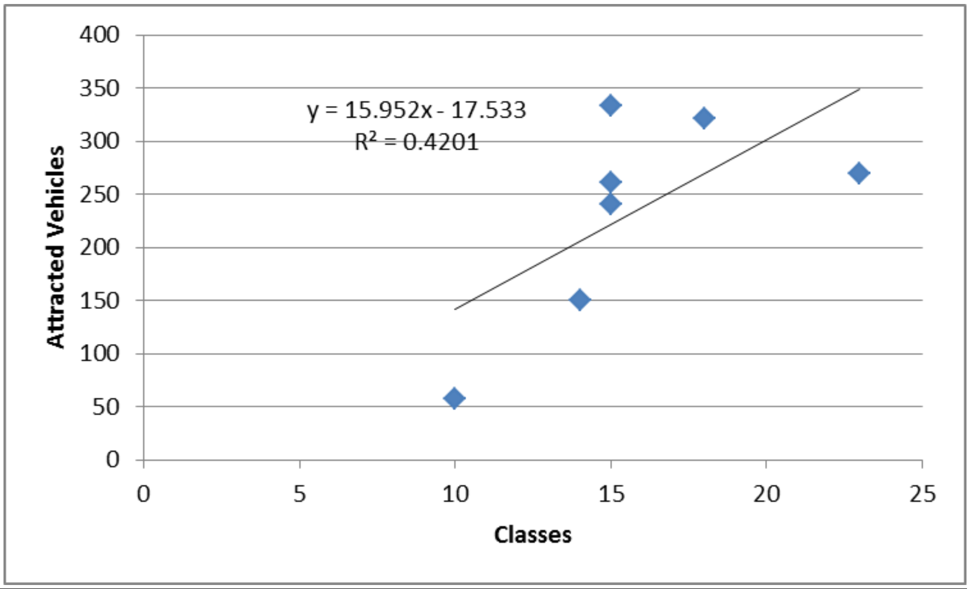
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.984794 |
| R Square | 0.969819 |
| Adjusted R Square | 0.803152 |
| Standard Error | 46.95462 |
| Observations | 7 |

ANOVA

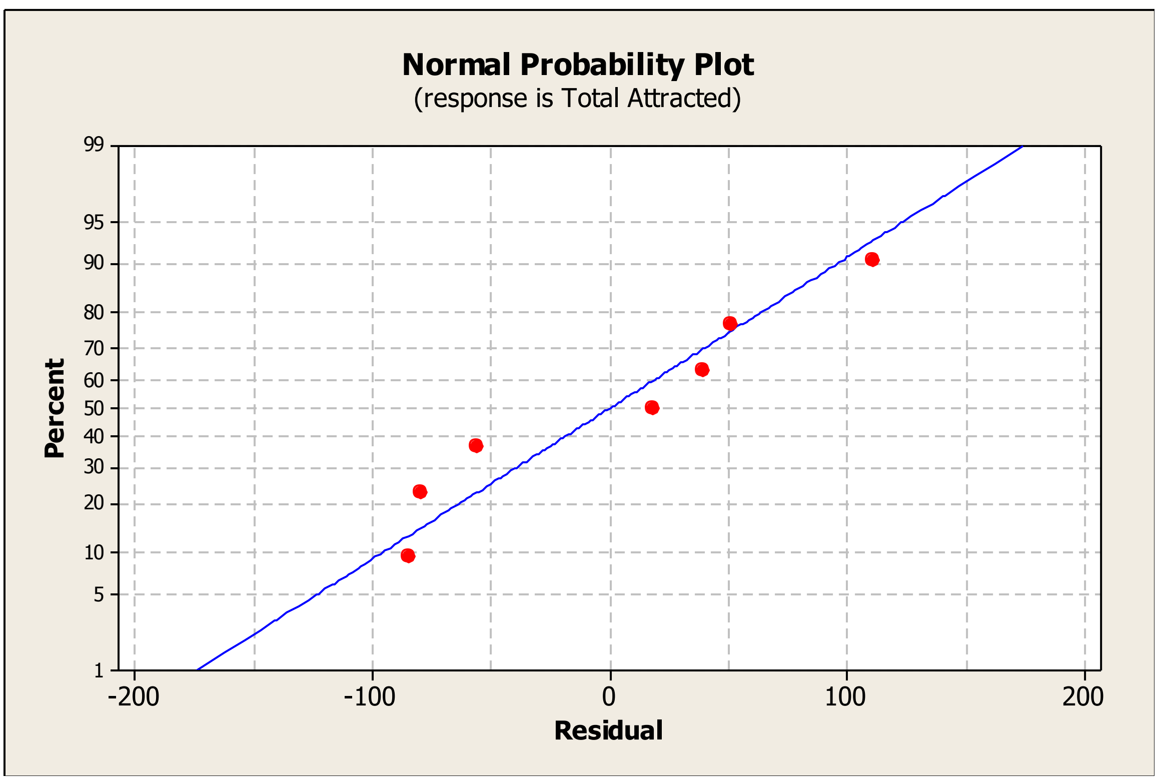
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 425071.6 | 425071.6 | 192.7993 | 3.481E-05 |
| Residual | 6 | 13228.42 | 2204.736 | | |
| Total | 7 | 438300 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Employees | 5.852078634 | 0.421461025 | 13.88522 | 8.69E-06 |

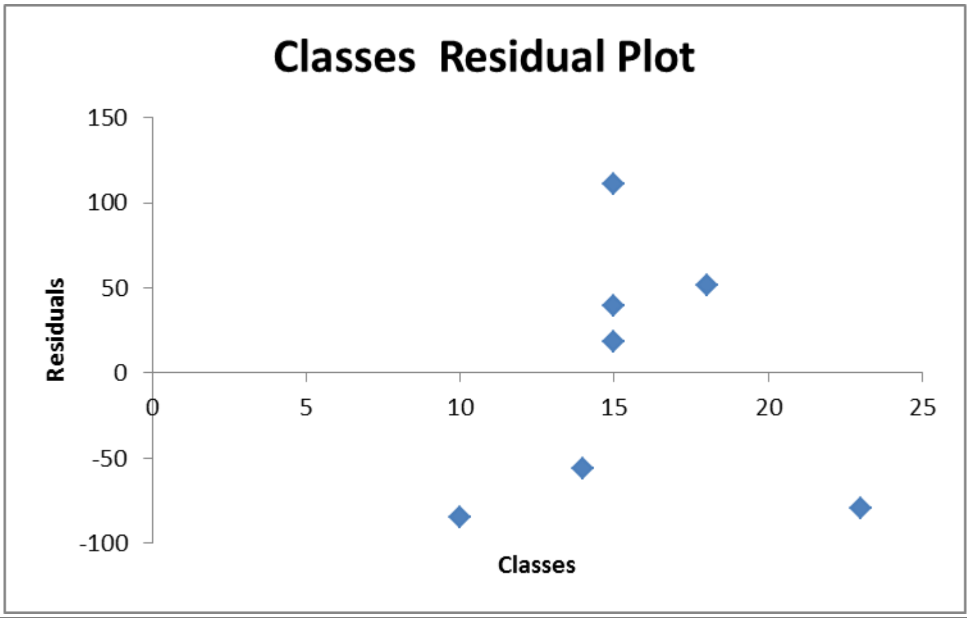
## Classrooms



y = 15.952x - 17.533
R² = 0.4201
Attracted Vehicles
Classes
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25

Normal Probability Plot
(response is Total Attracted)
Percent
Residual
99
95
90
80
70
60
50
40
30
20
10
5
1
-200
-100
0
100
200




SUMMARY OUTPUT

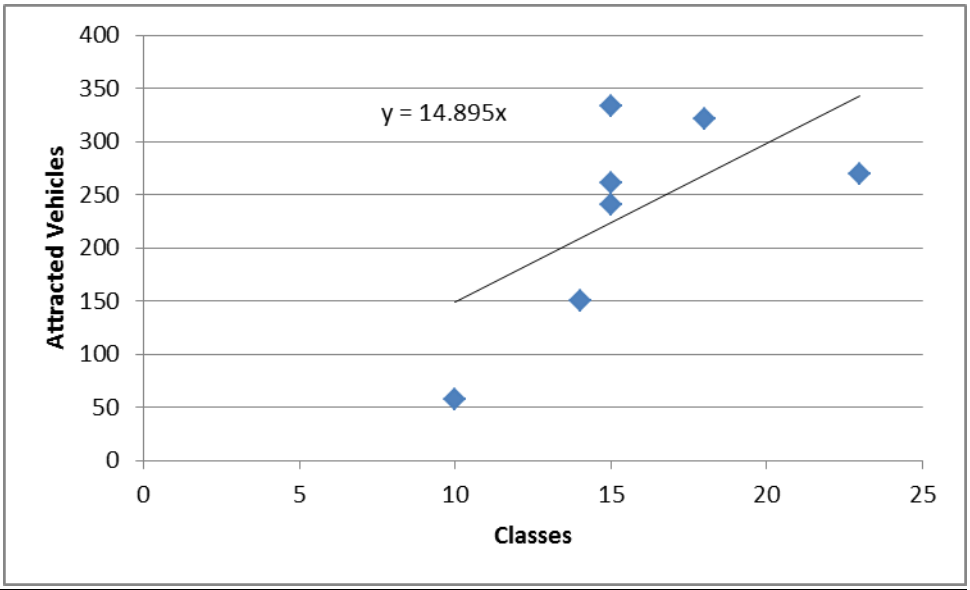
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.648115 |
| R Square | 0.420053 |
| Adjusted R Square | 0.304064 |
| Standard Error | 81.88676 |
| Observations | 7 |

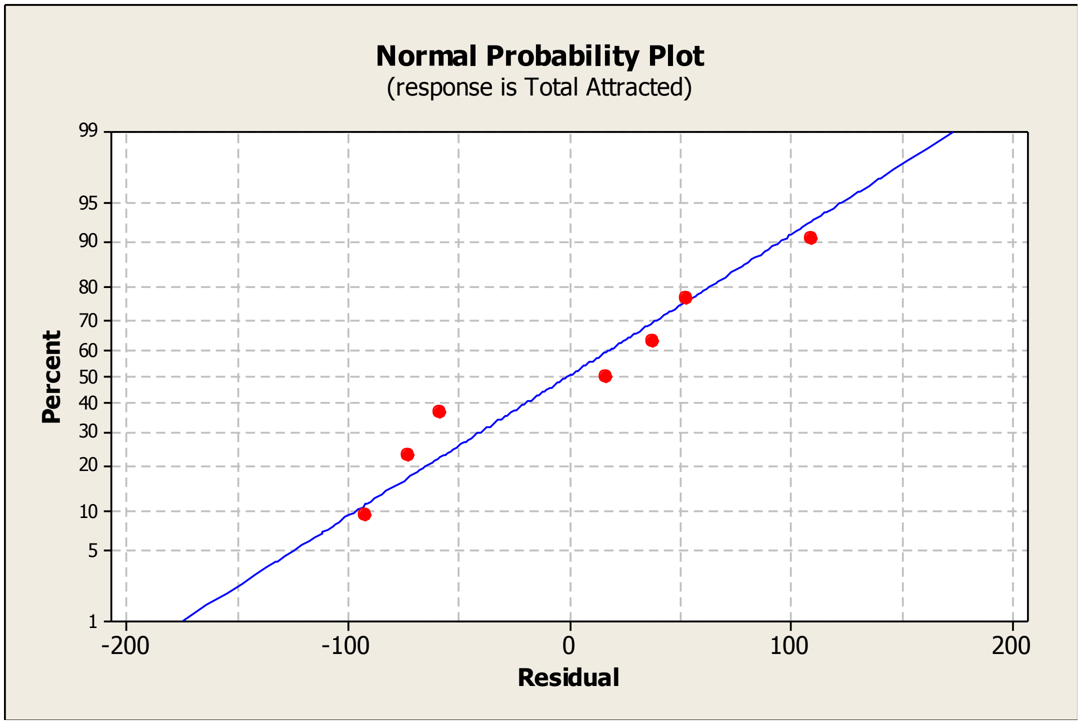
ANOVA

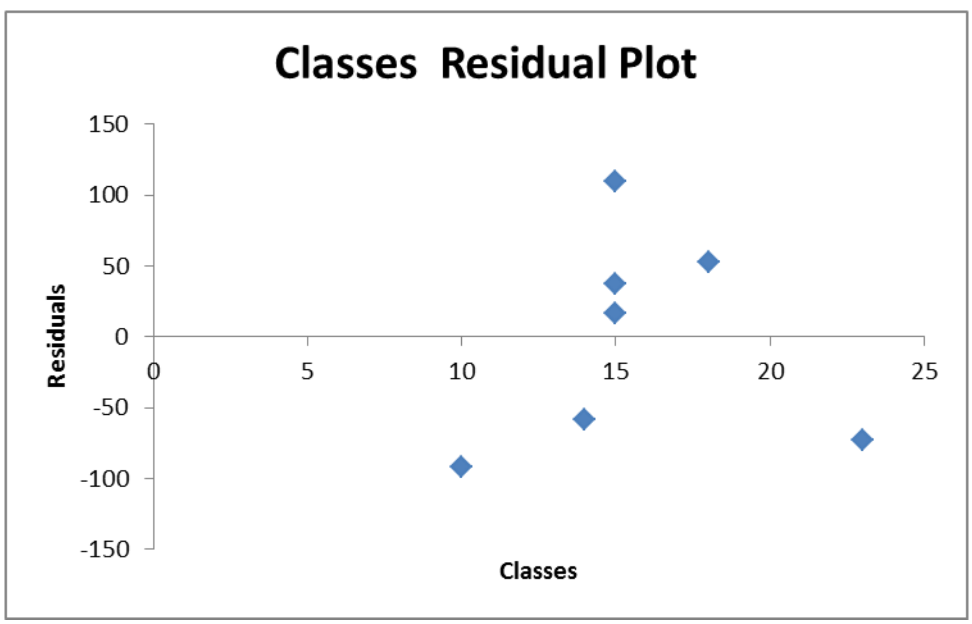
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 24283.65 | 24283.65 | 3.621484 | 0.115415236 |
| Residual | 5 | 33527.21 | 6705.442 | | |
| Total | 6 | 57810.86 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | -17.53293413 | 135.3124907 | -0.12957 | 0.901955 |
| Classes | 15.95209581 | 8.382517934 | 1.90302 | 0.115415 |

**<u>Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below</u>**




Normal Probability Plot
(response is Total Attracted)
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
-200
-100
0
100
200
Residual


Classes Residual Plot
Residuals
150
100
50
0
-50
-100
-150
0
5
10
15
20
25
Classes

SUMMARY OUTPUT

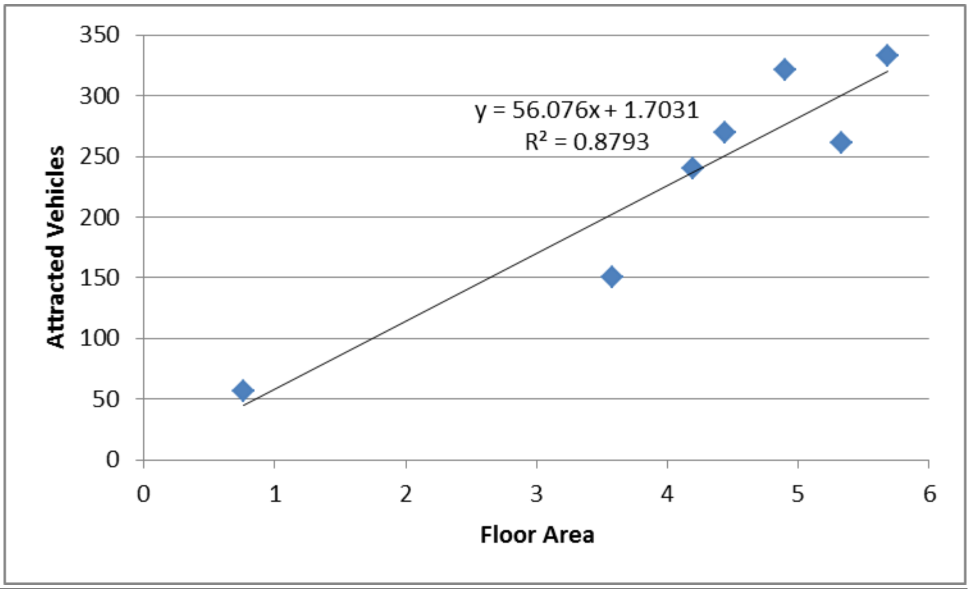
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.960859 |
| R Square | 0.923249 |
| Adjusted R Square | 0.756583 |
| Standard Error | 74.87744 |
| Observations | 7 |

ANOVA

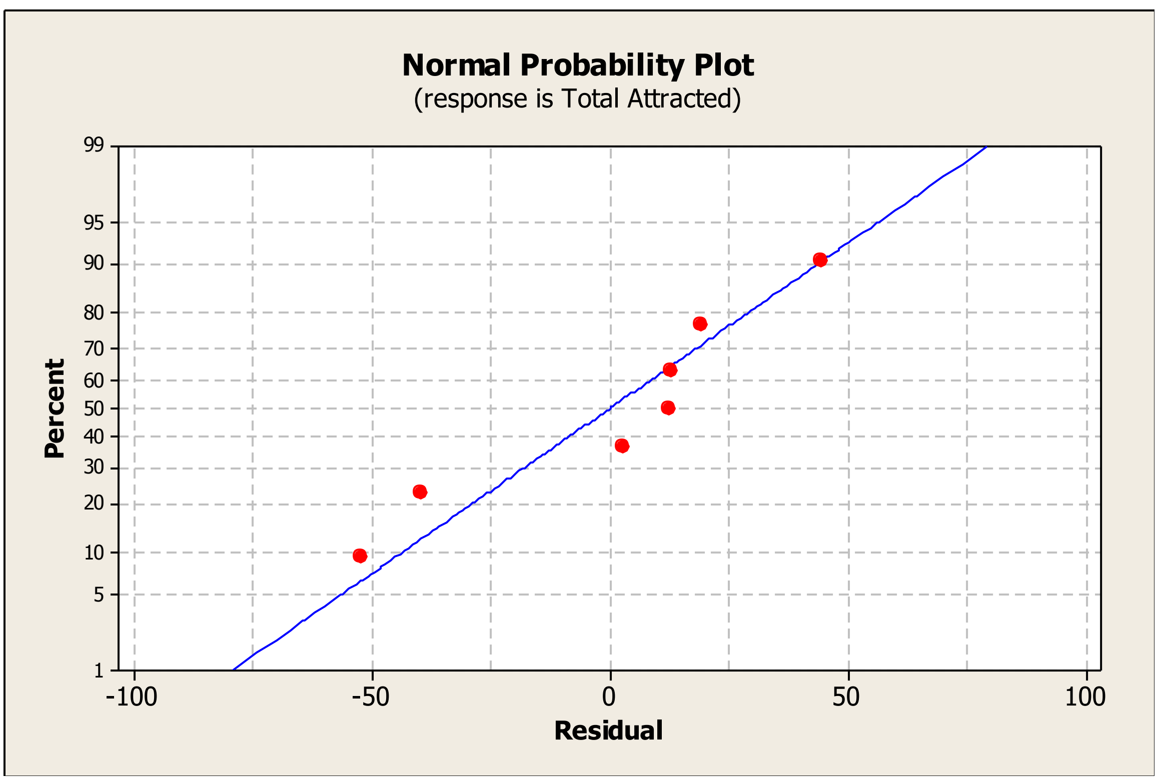
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 404660.2 | 404660.2 | 72.17528 | 0.000371476 |
| Residual | 6 | 33639.79 | 5606.632 | | |
| Total | 7 | 438300 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Classes | 14.89473684 | 1.753228785 | 8.495604 | 0.000146 |

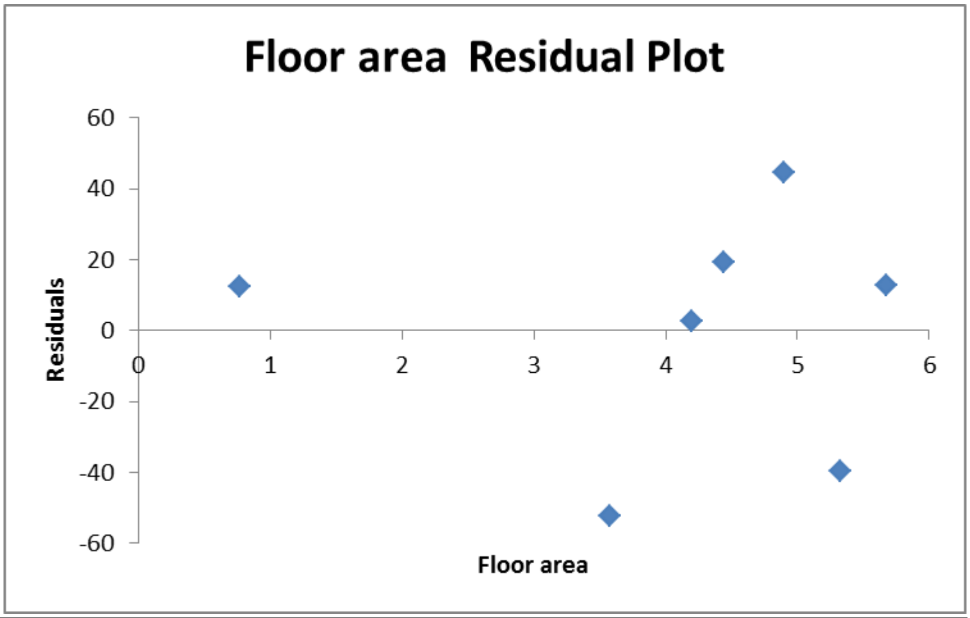
## Floor Area



y = 56.076x + 1.7031
R² = 0.8793
Attracted Vehicles
Floor Area
350
300
250
200
150
100
50
0
0
1
2
3
4
5
6

Normal Probability Plot
(response is Total Attracted)
Percent
Residual
99
95
90
80
70
60
50
40
30
20
10
5
1
-100
-50
0
50
100




SUMMARY
OUTPUT

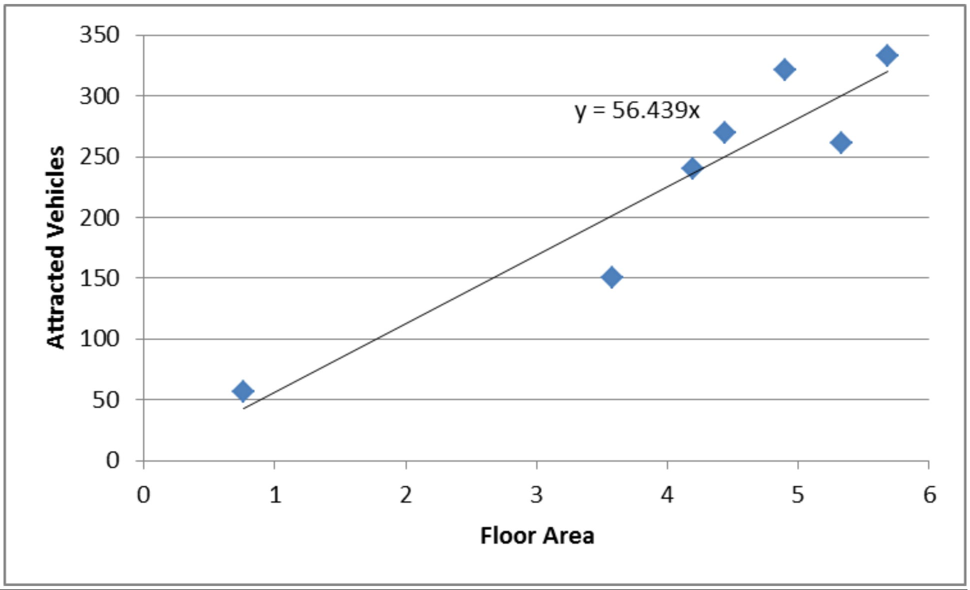
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.937728 |
| R Square | 0.879333 |
| Adjusted R Square | 0.855199 |
| Standard Error | 37.35202 |
| Observations | 7 |

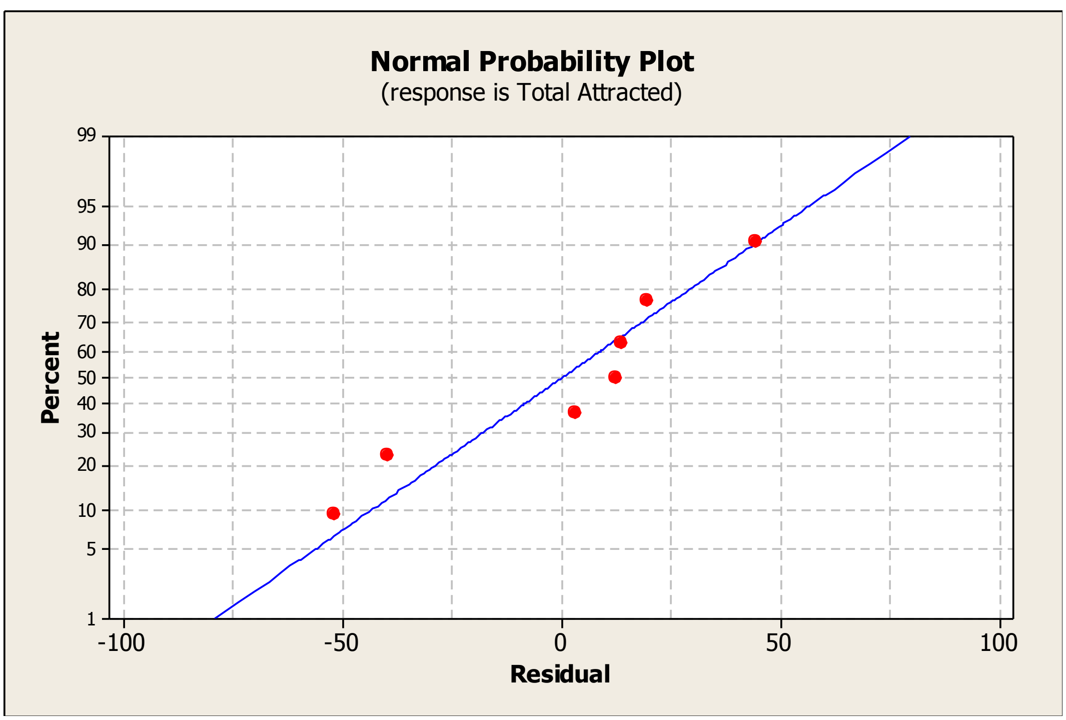
ANOVA

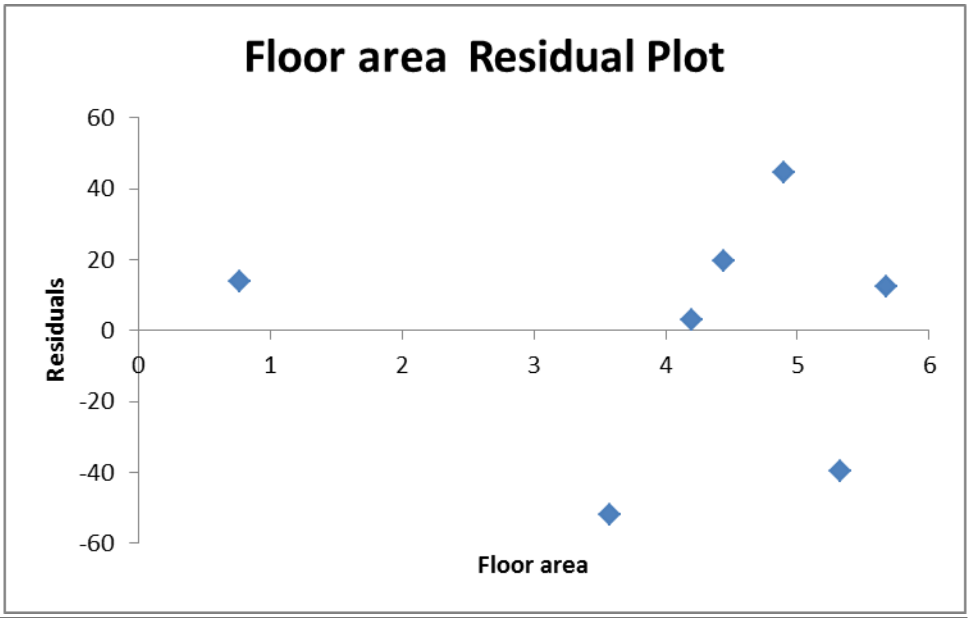
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 50834.99 | 50834.99 | 36.43632 | 0.001797008 |
| Residual | 5 | 6975.868 | 1395.174 | | |
| Total | 6 | 57810.86 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 1.703059086 | 40.85820076 | 0.041682 | 0.968365 |
| Floor area | 56.07554555 | 9.289797666 | 6.03625 | 0.001797 |

**Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below**






SUMMARY OUTPUT

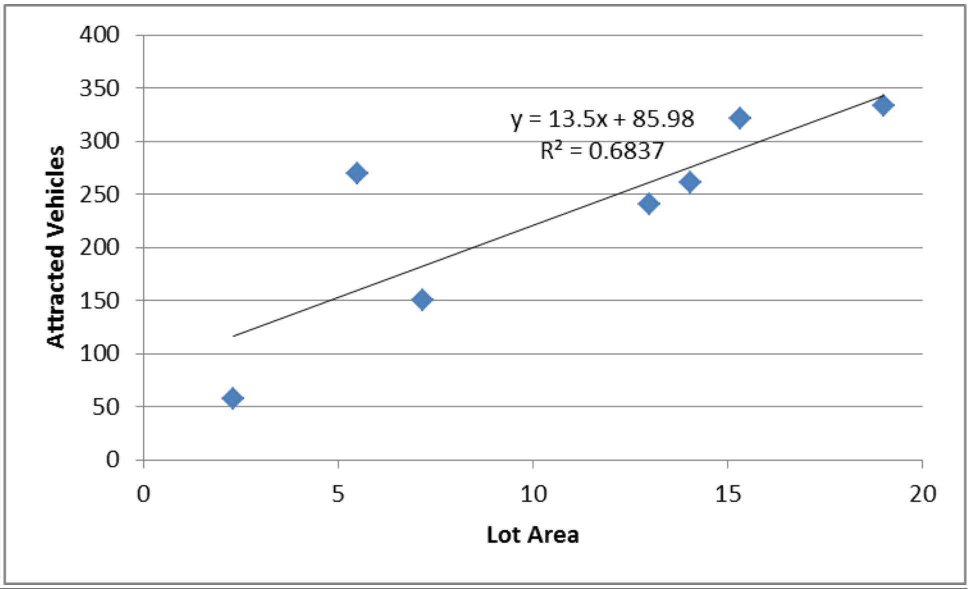
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.992007 |
| R Square | 0.984079 |
| Adjusted R Square | 0.817412 |
| Standard Error | 34.1035 |
| Observations | 7 |

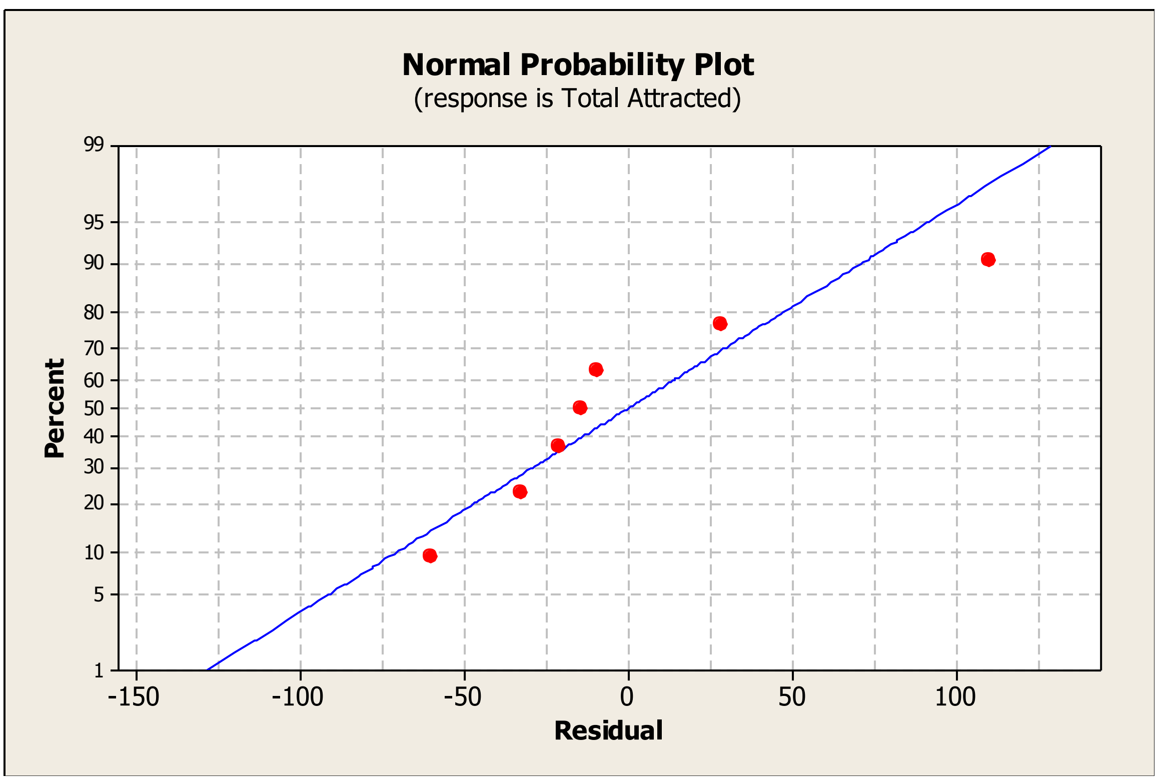
ANOVA

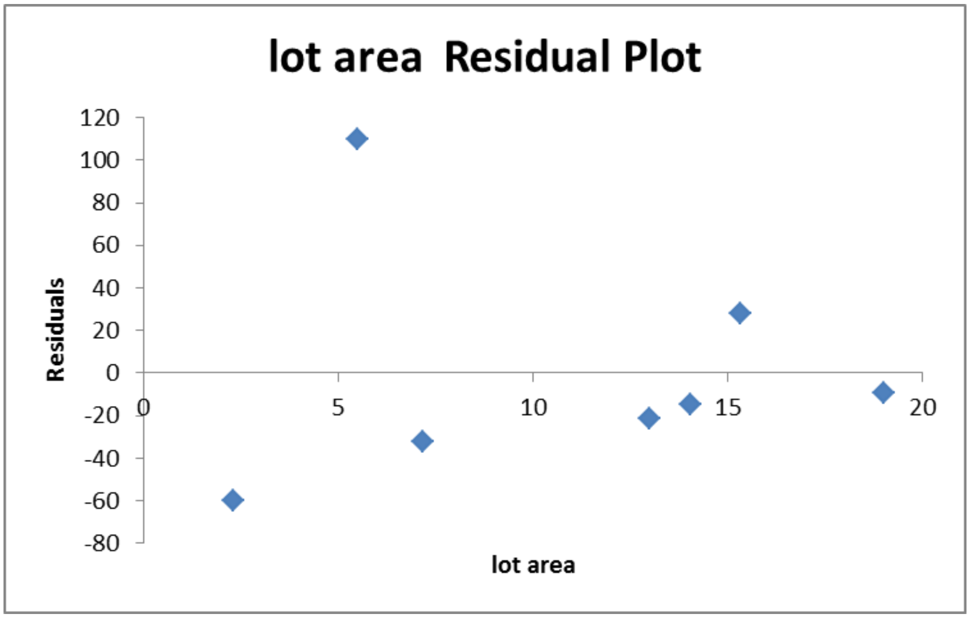
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 431321.7 | 431321.7 | 370.8544 | 6.96353E-06 |
| Residual | 6 | 6978.292 | 1163.049 | | |
| Total | 7 | 438300 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Floor area | 56.43891489 | 2.93073757 | 19.25758 | 1.27E-06 |

## Lot Area


y = 13.5x + 85.98
R² = 0.6837
Attracted Vehicles
Lot Area
400
350
300
250
200
150
100
50
0
0
5
10
15
20


Normal Probability Plot
(response is Total Attracted)
Percent
Residual
99
95
90
80
70
60
50
40
30
20
10
5
1
-150
-100
-50
0
50
100




SUMMARY OUTPUT

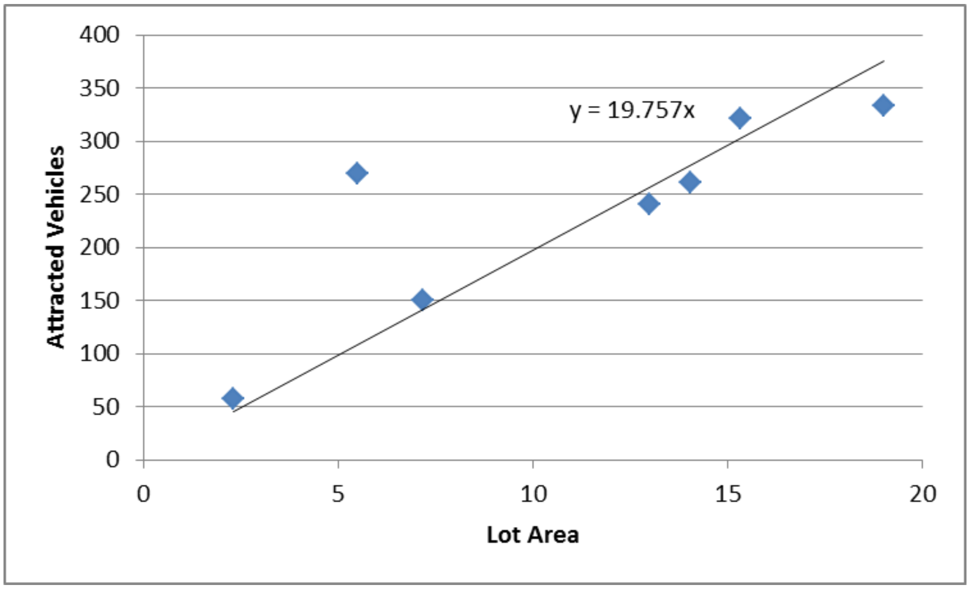
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.826886 |
| R Square | 0.683741 |
| Adjusted R Square | 0.620489 |
| Standard Error | 60.47019 |
| Observations | 7 |

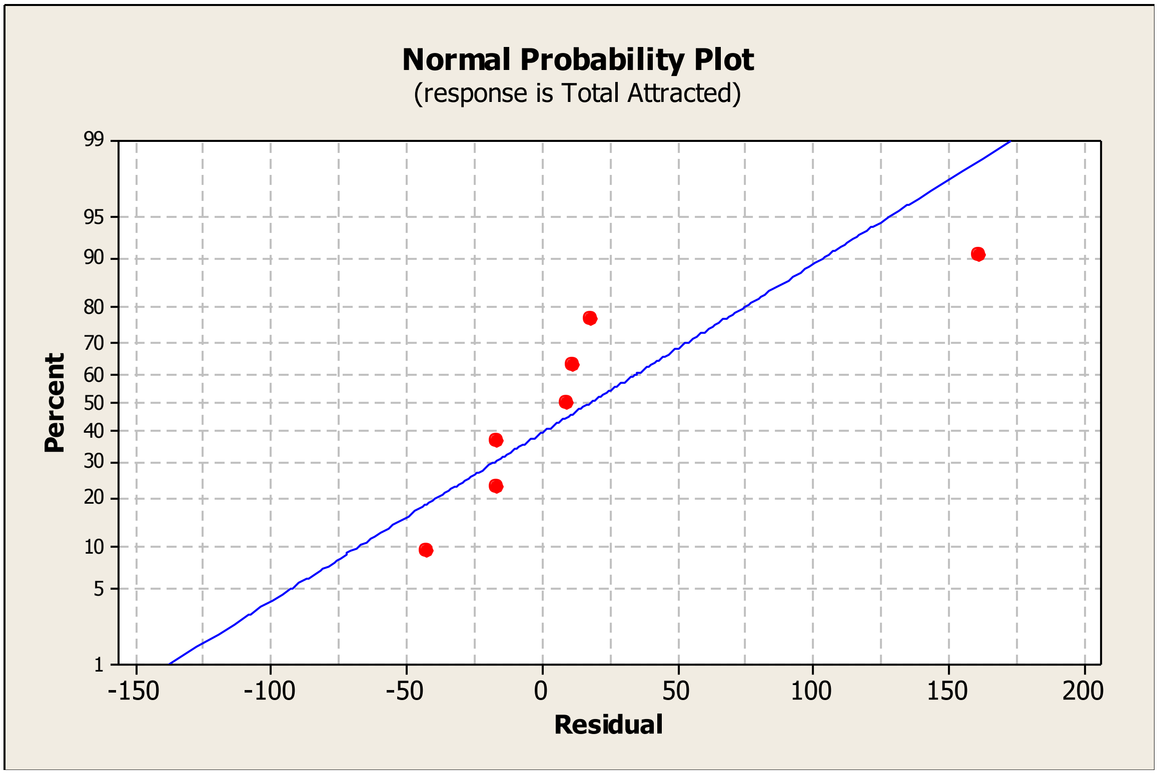
ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 39527.64 | 39527.64 | 10.80981 | 0.021765617 |
| Residual | 5 | 18283.22 | 3656.644 | | |
| Total | 6 | 57810.86 | | | |

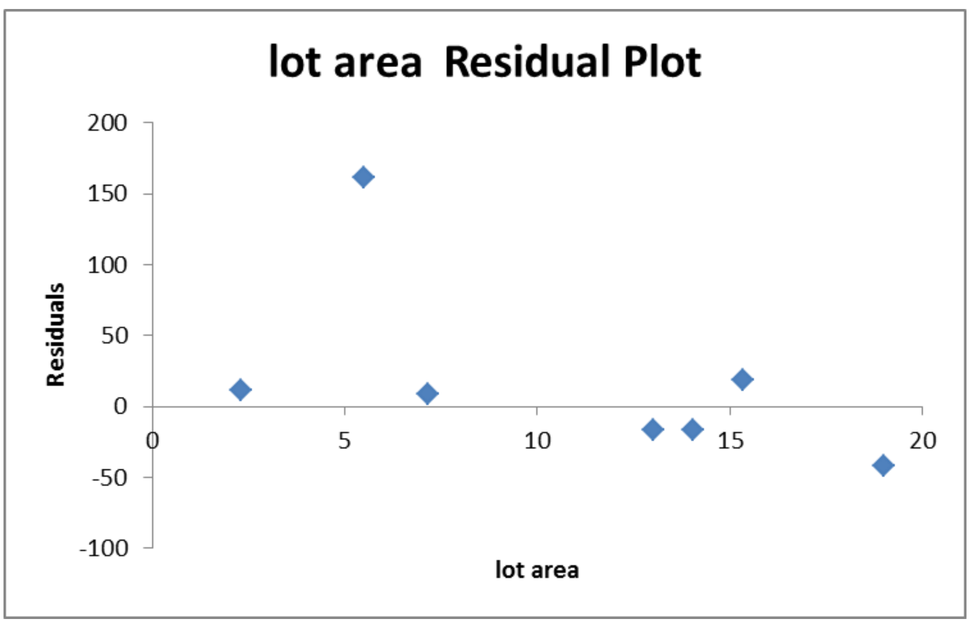
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 85.97951002 | 50.25773775 | 1.710772 | 0.14781 |
| lot area | 13.50033982 | 4.106157896 | 3.287828 | 0.021766 |

**<u>Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below</u>**





Normal Probability Plot
(response is Total Attracted)
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
-150
-100
-50
0
50
100
150
200
Residual

lot area Residual Plot
Residuals
200
150
100
50
0
-50
-100
0
5
10
15
20
lot area

SUMMARY OUTPUT

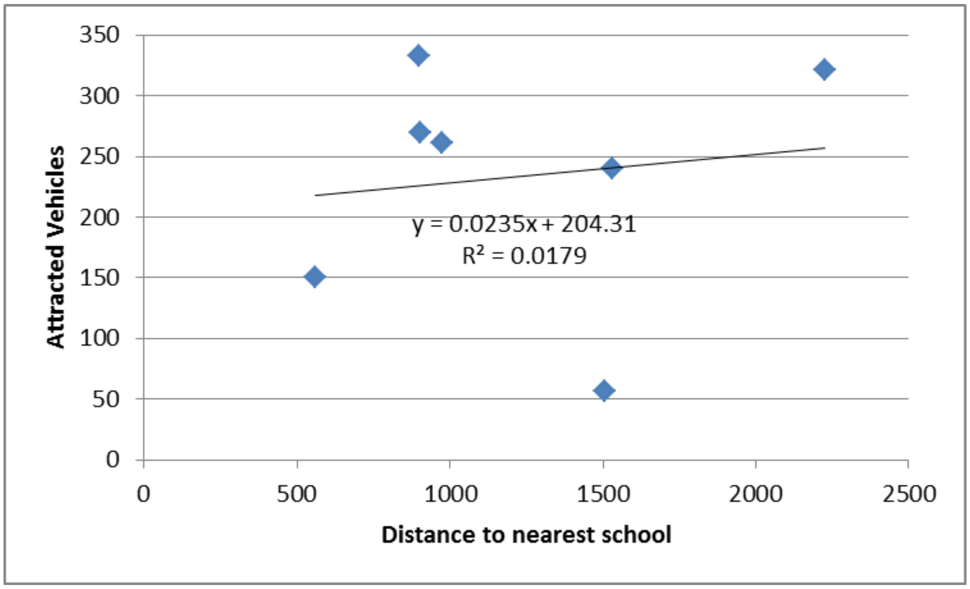
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.966369 |
| R Square | 0.933869 |
| Adjusted R Square | 0.767202 |
| Standard Error | 69.50452 |
| Observations | 7 |

ANOVA

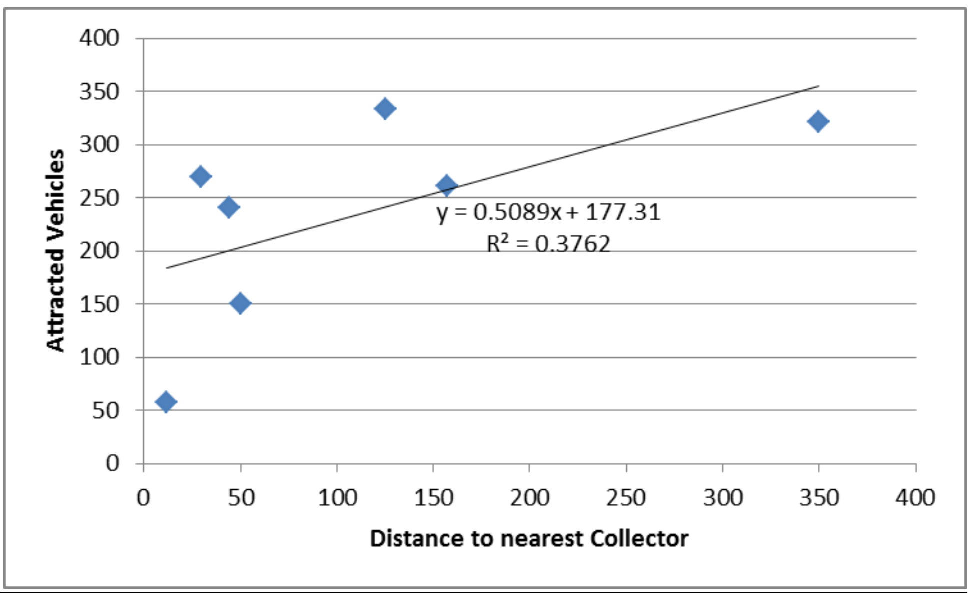
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 409314.7 | 409314.7 | 84.72885 | 0.000253991 |
| Residual | 6 | 28985.27 | 4830.878 | | |
| Total | 7 | 438300 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Lot area | 19.75660778 | 2.146331097 | 9.204828 | 9.27E-05 |

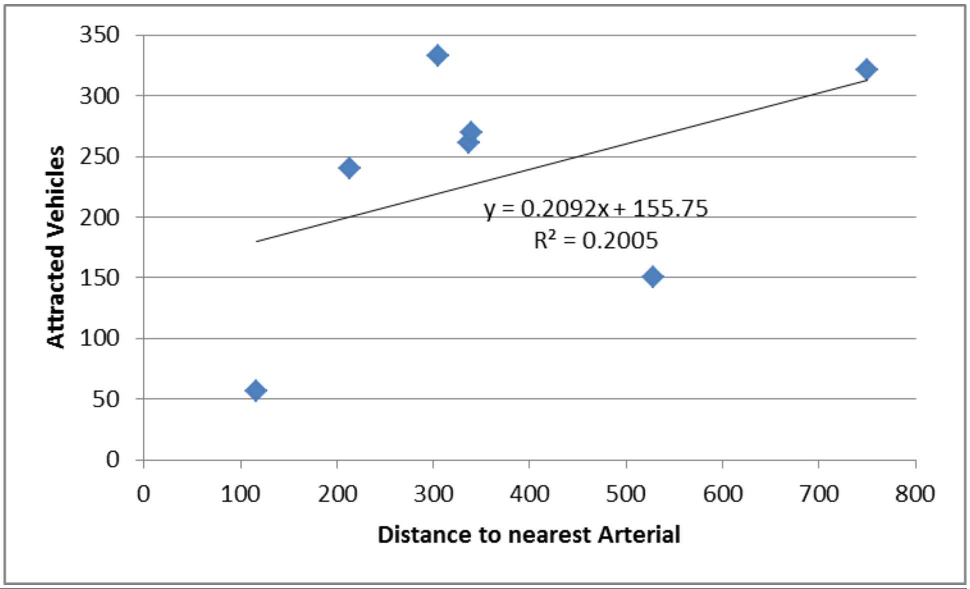
## Distance to nearest school



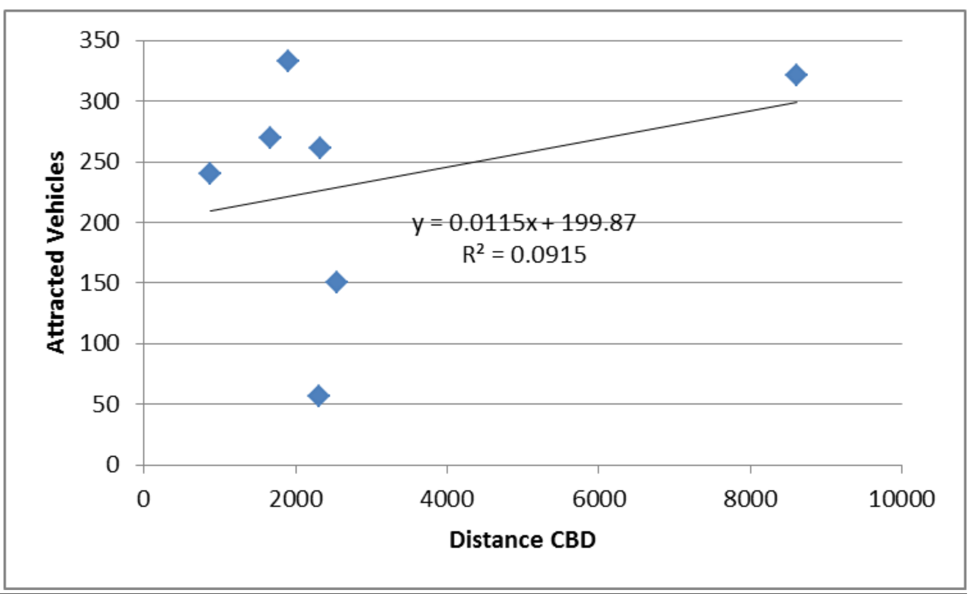

## Distance to nearest collector



## Distance to the nearest arterial

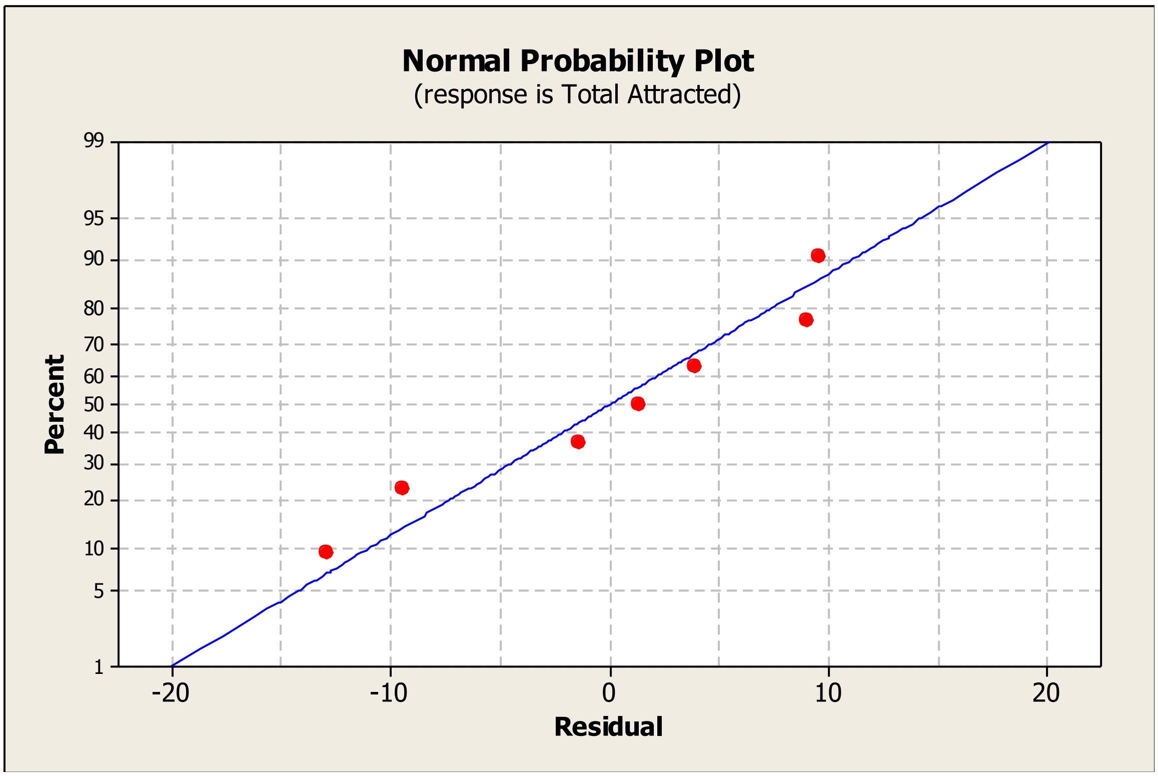


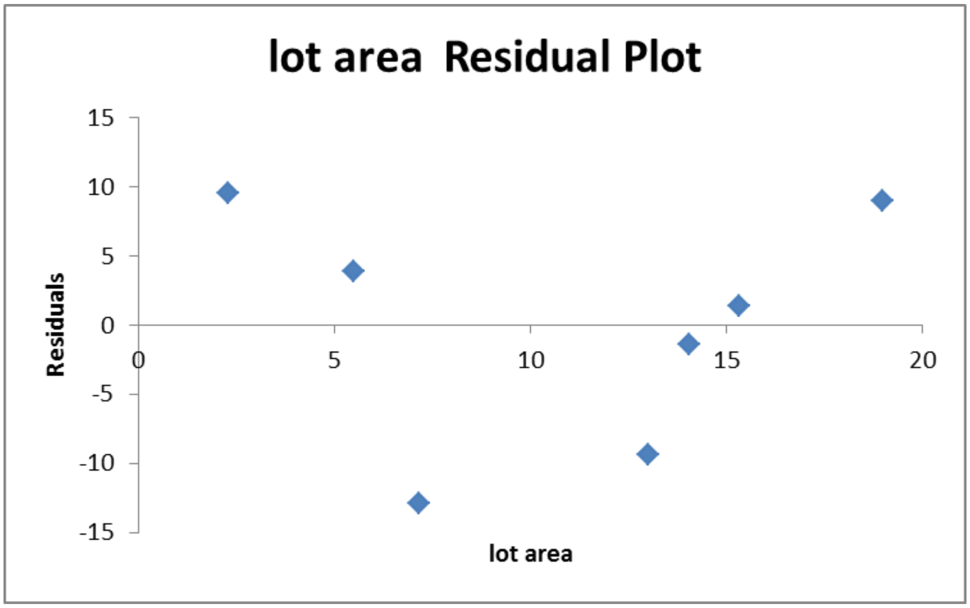

## Distance to CBD

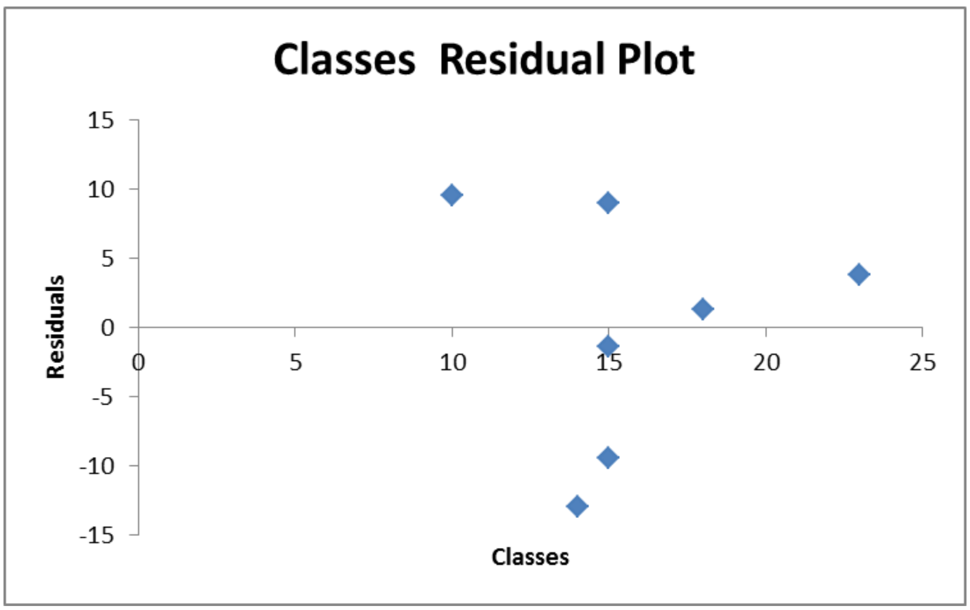


## Multiple linear regression

| |
|---|
| **Attracted vehicles = -118.74+13.77*Classes+12.44*Lot Area    $R^2$=0.992** |




lot area Residual Plot
Residuals
lot area
15
10
5
0
-5
-10
-15
0
5
10
15
20


Classes Residual Plot
Residuals
Classes
15
10
5
0
-5
-10
-15
0
5
10
15
20
25

SUMMARY OUTPUT

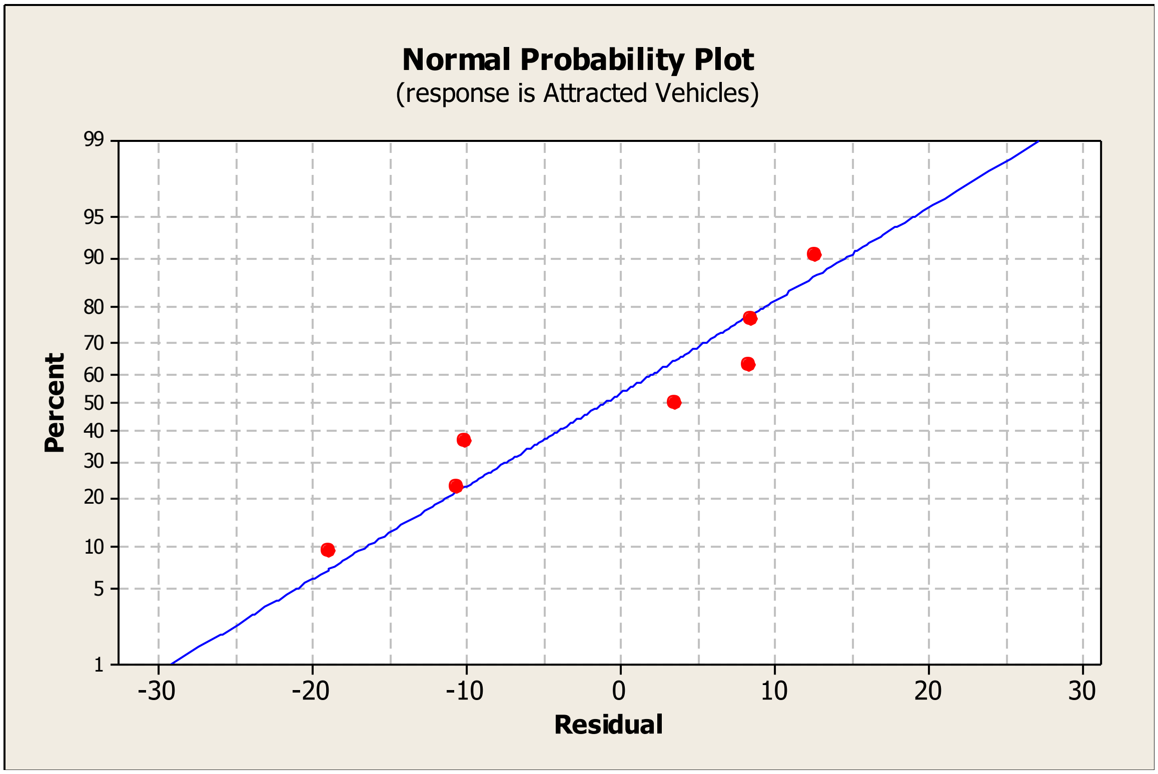
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.996144 |
| R Square | 0.992302 |
| Adjusted R Square | 0.988453 |
| Standard Error | 10.54769 |
| Observations | 7 |

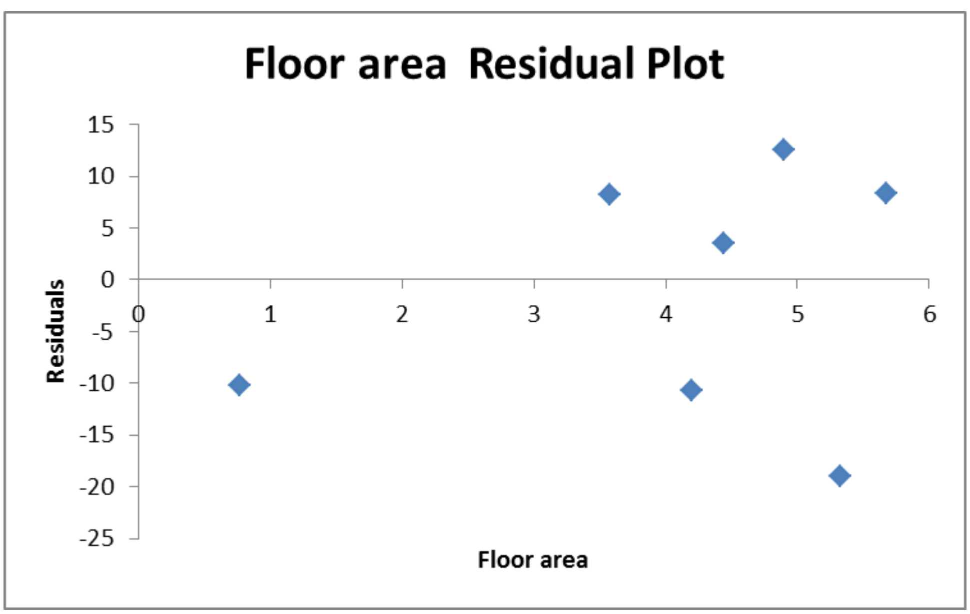
ANOVA

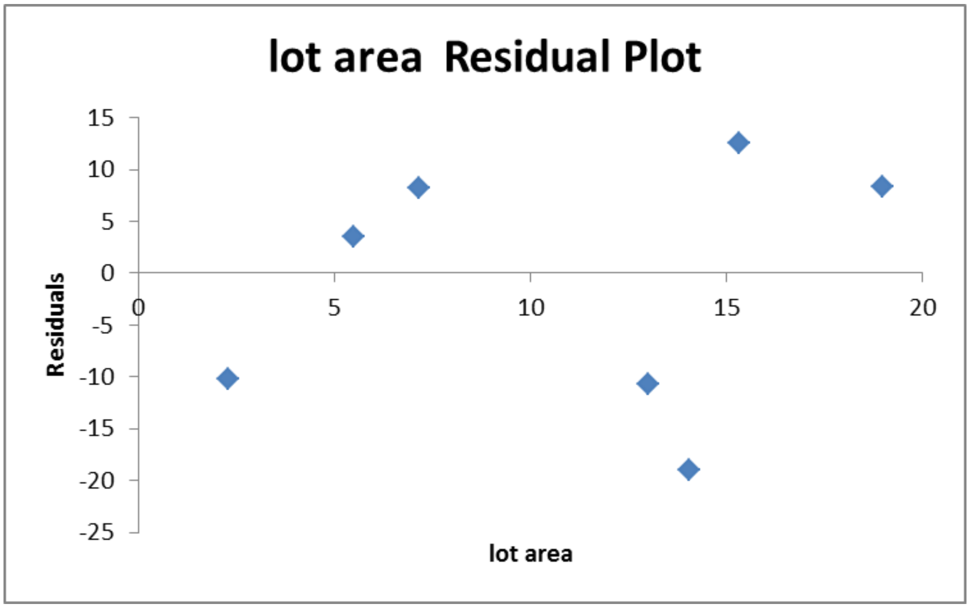
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 57365.84 | 28682.92 | 257.8155 | 5.92557E-05 |
| Residual | 4 | 445.0147 | 111.2537 | | |
| Total | 6 | 57810.86 | | | |

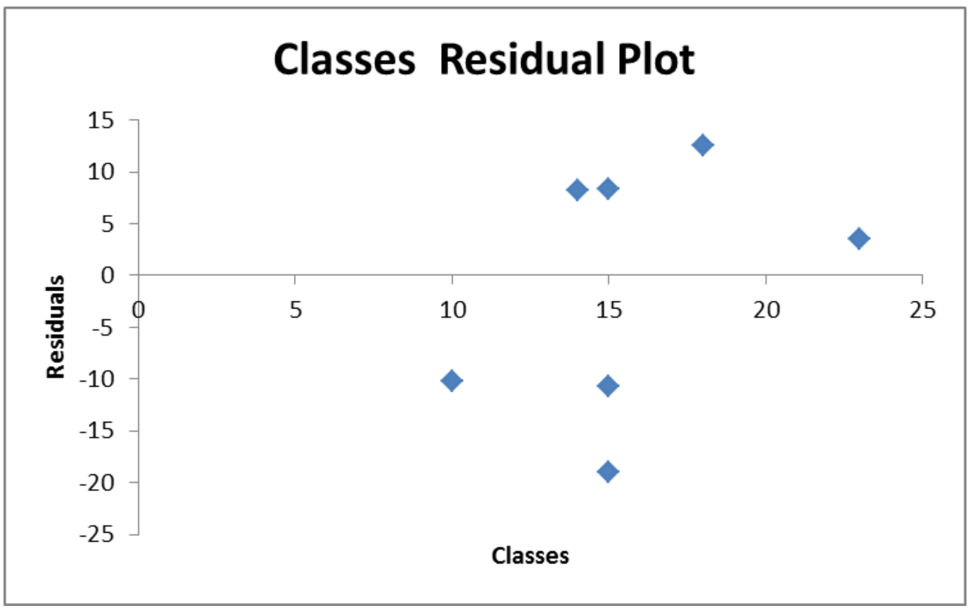
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | -118.737 | 18.3909388 | -6.45627 | 0.002963 |
| Classes | 13.76605 | 1.087153513 | 12.66247 | 0.000224 |
| Lot area | 12.43553 | 0.721147942 | 17.24408 | 6.64E-05 |

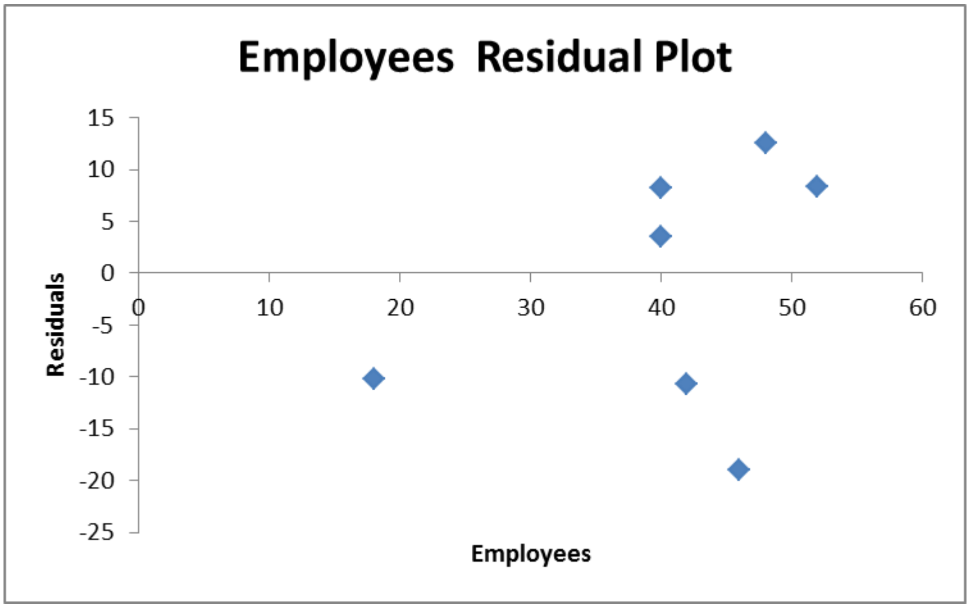
**Attracted vehicles = 13.049*Classes+14.84*Lot Area-6.98*Employees+36.94*Floor Area** **$R^2$=0.998**




lot area Residual Plot
15
10
5
0
-5
-10
-15
-20
-25
Residuals
0
5
10
15
20
lot area


Classes Residual Plot
15
10
5
0
-5
-10
-15
-20
-25
Residuals
0
5
10
15
20
25
Classes




SUMMARY OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.998985 |
| R Square | 0.997972 |
| Adjusted R Square | 0.66261 |
| Standard Error | 17.2148 |
| Observations | 7 |

ANOVA

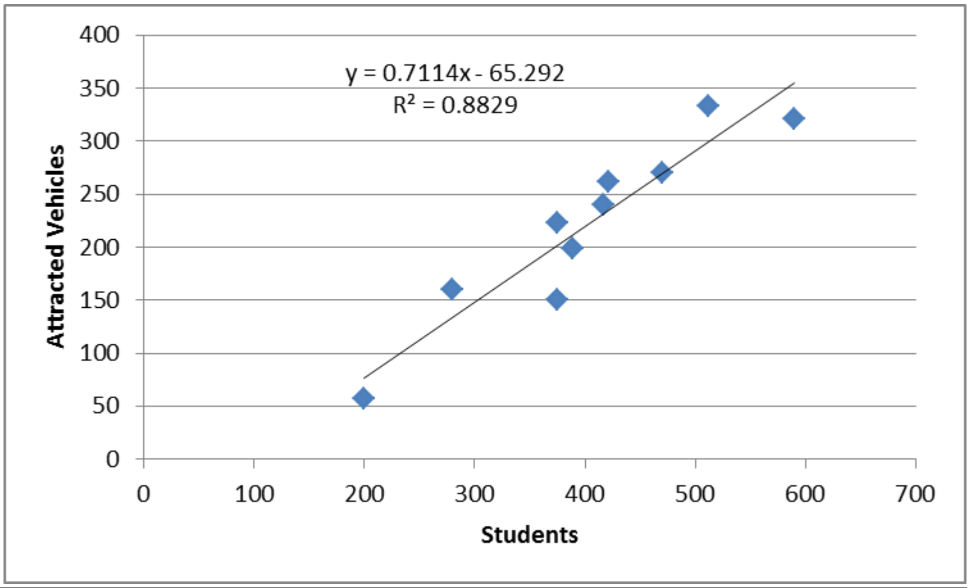
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 4 | 437411 | 109352.7 | 368.9993 | 0.002704534 |
| Residual | 3 | 889.0483 | 296.3494 | | |
| Total | 7 | 438300 | | | |

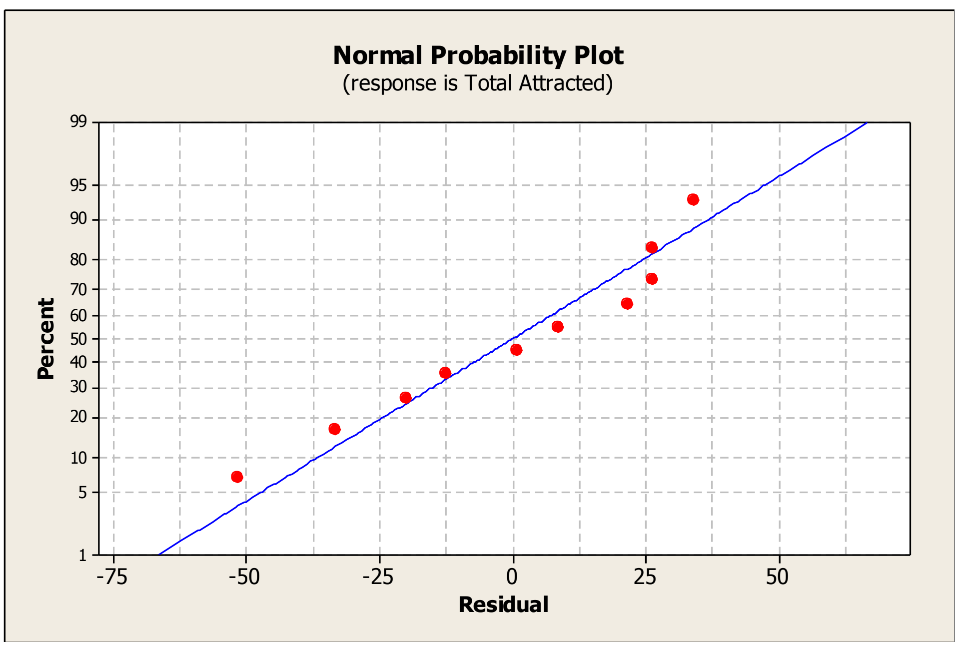
| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Employees | -6.97825868 | 2.044903997 | -3.41251 | 0.042073 |
| Classes | 13.04946904 | 2.976327232 | 4.38442 | 0.021971 |
| Lot area | 14.84117211 | 3.517187294 | 4.219614 | 0.02433 |
| Floor area | 36.93643246 | 13.4263769 | 2.751035 | 0.070681 |

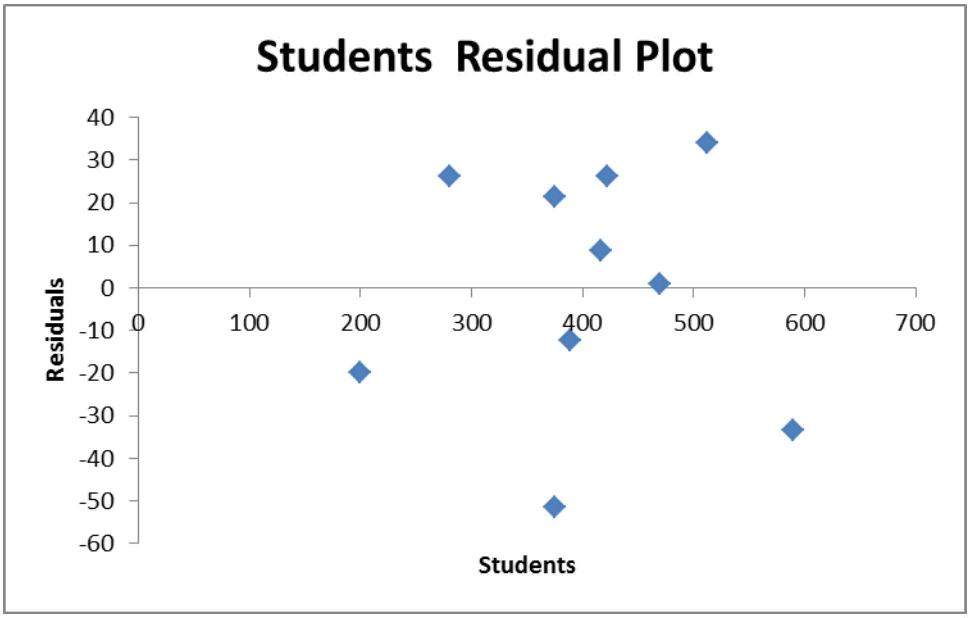
## Data analysis using all of the 10 schools

## Simple linear regression

### Students






SUMMARY
OUTPUT

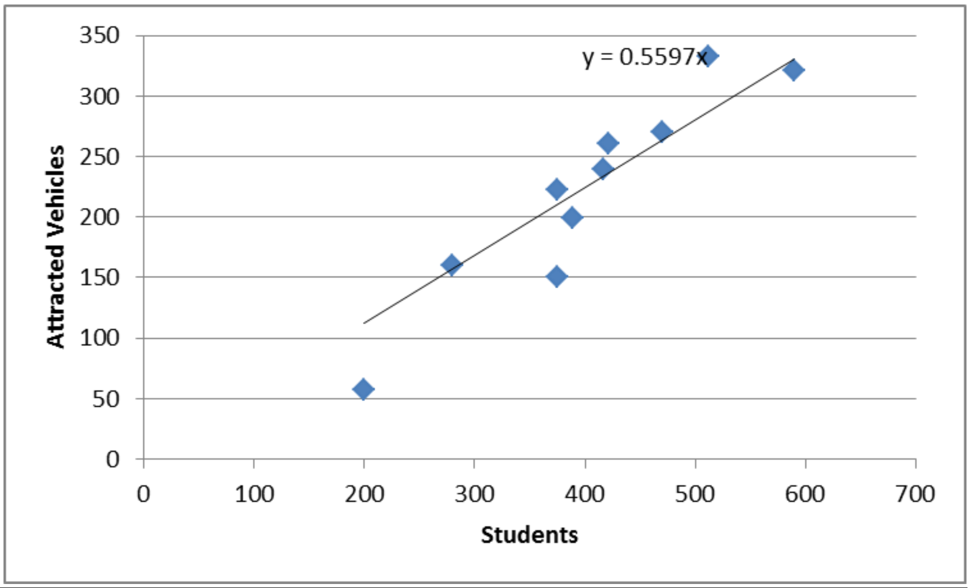
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.939635 |
| R Square | 0.882914 |
| Adjusted R Square | 0.868278 |
| Standard Error | 30.3775 |
| Observations | 10 |

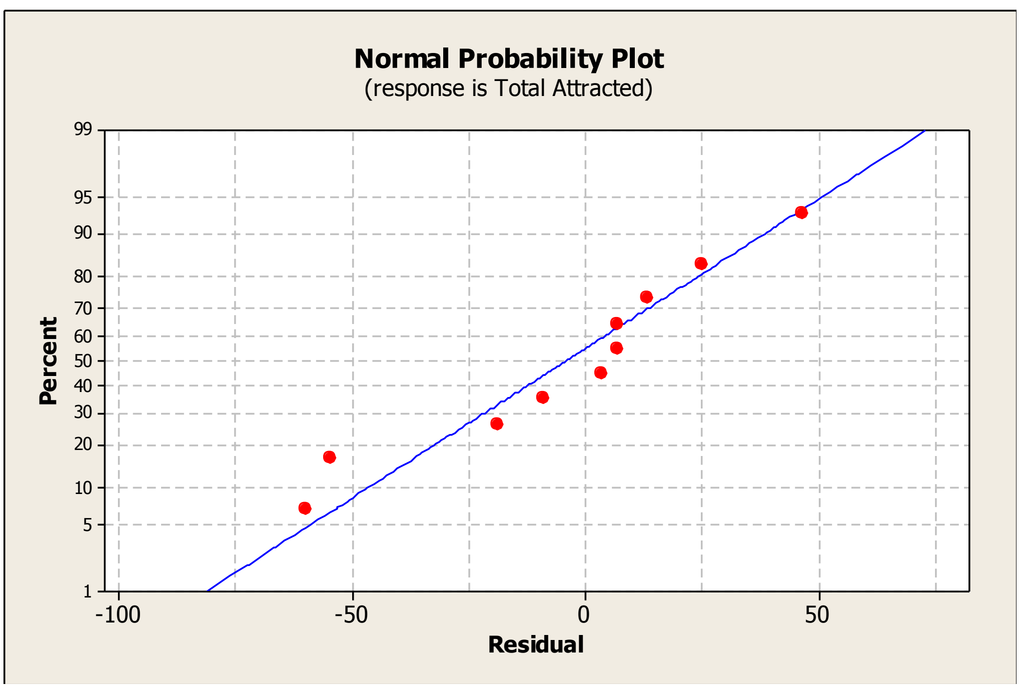
ANOVA

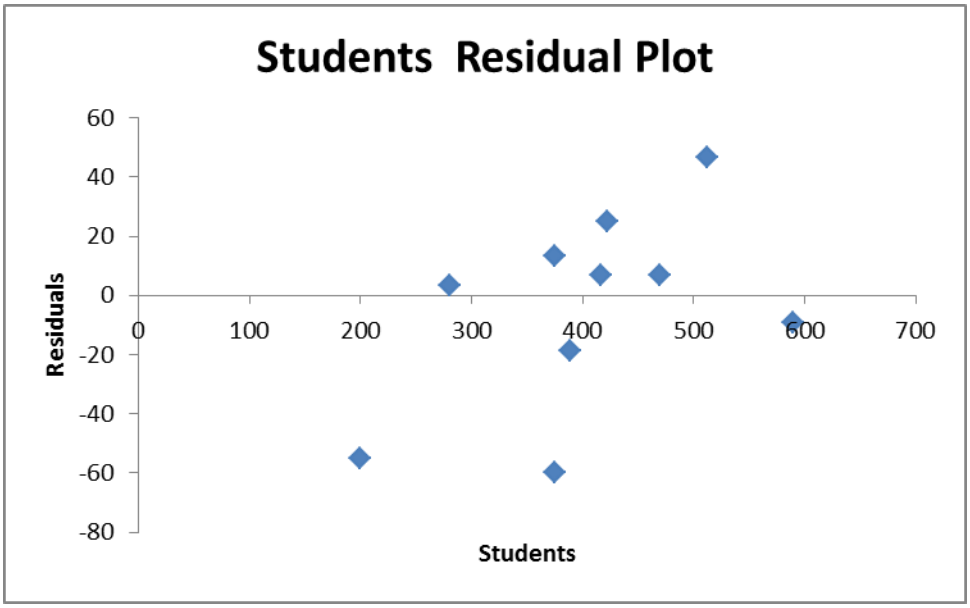
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 55668.06 | 55668.06 | 60.32567 | 5.39896E-05 |
| Residual | 8 | 7382.338 | 922.7922 | | |
| Total | 9 | 63050.4 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | -65.292085 | 38.14126878 | -1.71185 | 0.125284 |
| Students | 0.71139475 | 0.091592428 | 7.76696 | 5.4E-05 |

**<u>Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below</u>**






SUMMARY OUTPUT

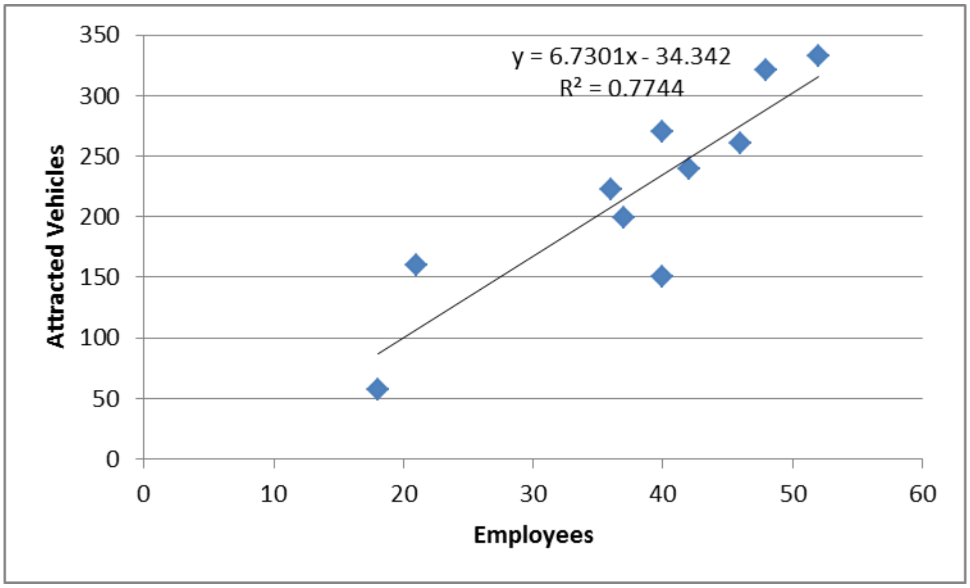
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.990842 |
| R Square | 0.981768 |
| Adjusted R Square | 0.870657 |
| Standard Error | 33.47721 |
| Observations | 10 |

ANOVA

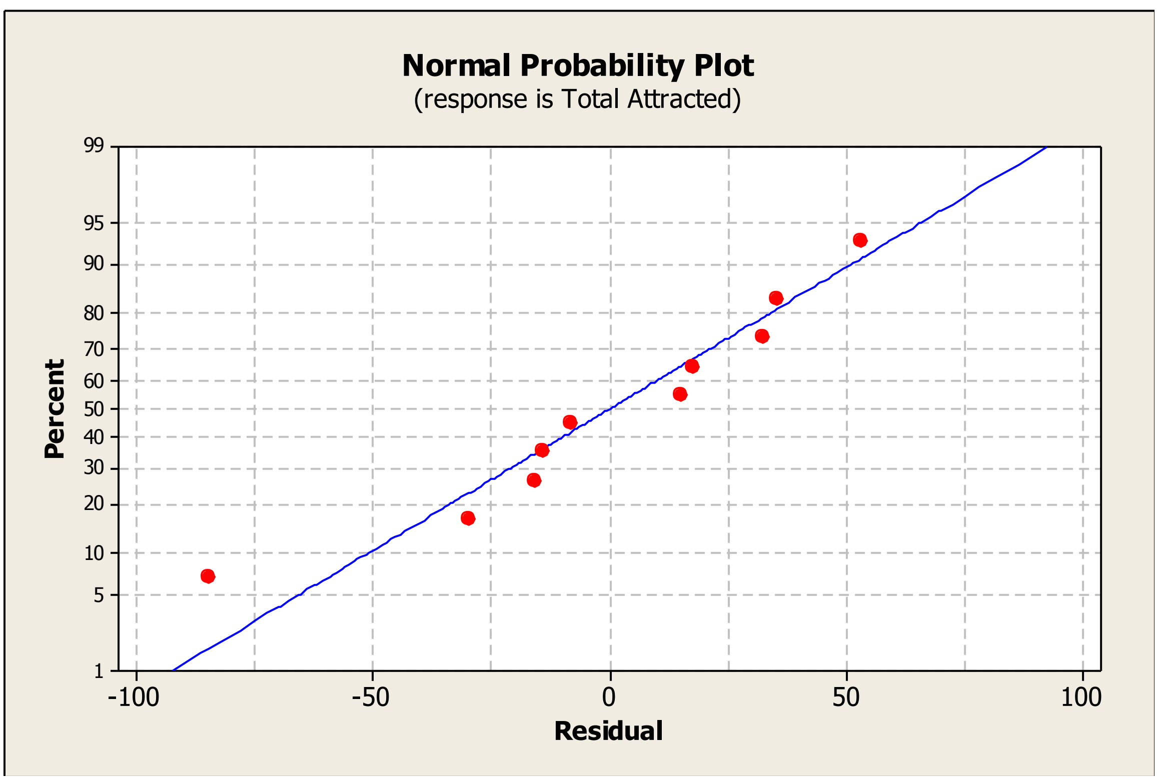
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 543143.5 | 543143.5 | 484.6364 | 1.91405E-08 |
| Residual | 9 | 10086.51 | 1120.724 | | |
| Total | 10 | 553230 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Students | 0.559656719 | 0.025422233 | 22.01446 | 3.89E-09 |

## Employees



y = 6.7301x - 34.342
R² = 0.7744
Attracted Vehicles
Employees
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60

Normal Probability Plot
(response is Total Attracted)
Percent
Residual
99
95
90
80
70
60
50
40
30
20
10
5
1
-100
-50
0
50
100


SUMMARY OUTPUT

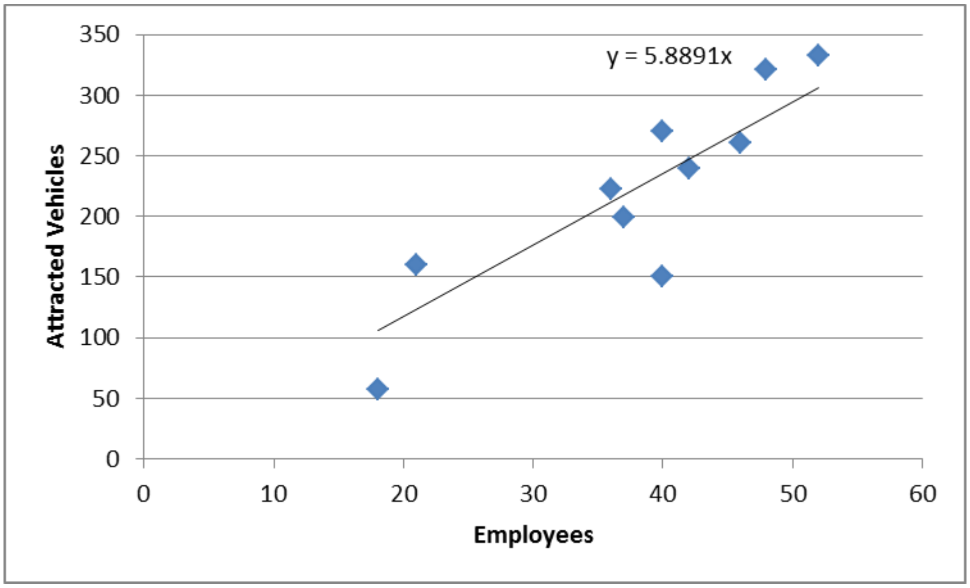
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.880003 |
| R Square | 0.774405 |
| Adjusted R Square | 0.746206 |
| Standard Error | 42.16611 |
| Observations | 10 |

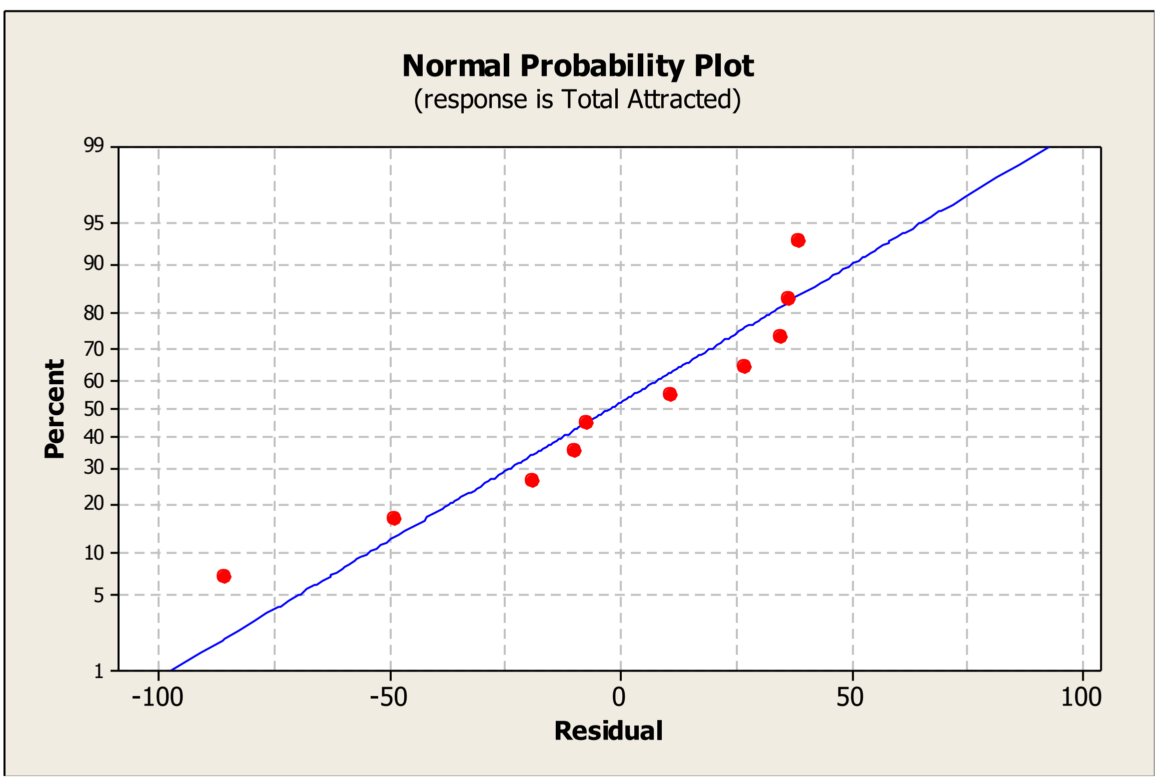
ANOVA

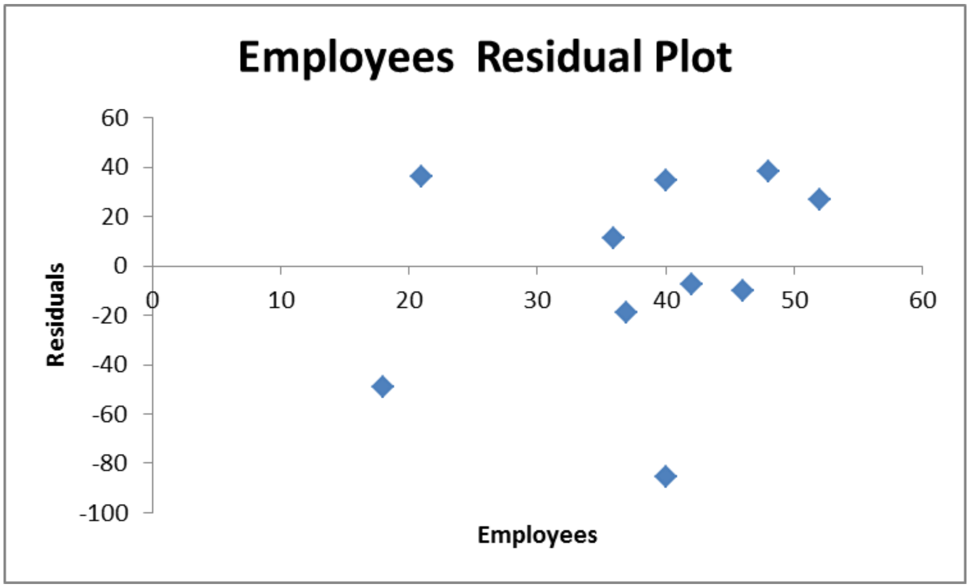
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 48826.55 | 48826.55 | 27.4618 | 0.00078291 |
| Residual | 8 | 14223.85 | 1777.981 | | |
| Total | 9 | 63050.4 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | -34.34211503 | 50.59085552 | -0.67882 | 0.516405 |
| Employees | 6.730055659 | 1.28426353 | 5.240401 | 0.000783 |

**<u>Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below</u>**






SUMMARY OUTPUT

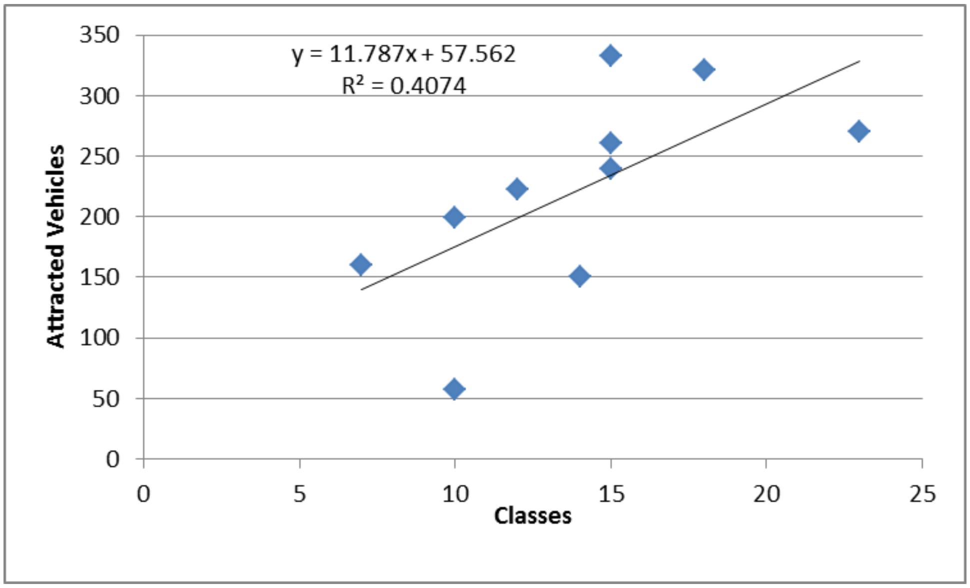
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.986311 |
| R Square | 0.972809 |
| Adjusted R Square | 0.861697 |
| Standard Error | 40.88349 |
| Observations | 10 |

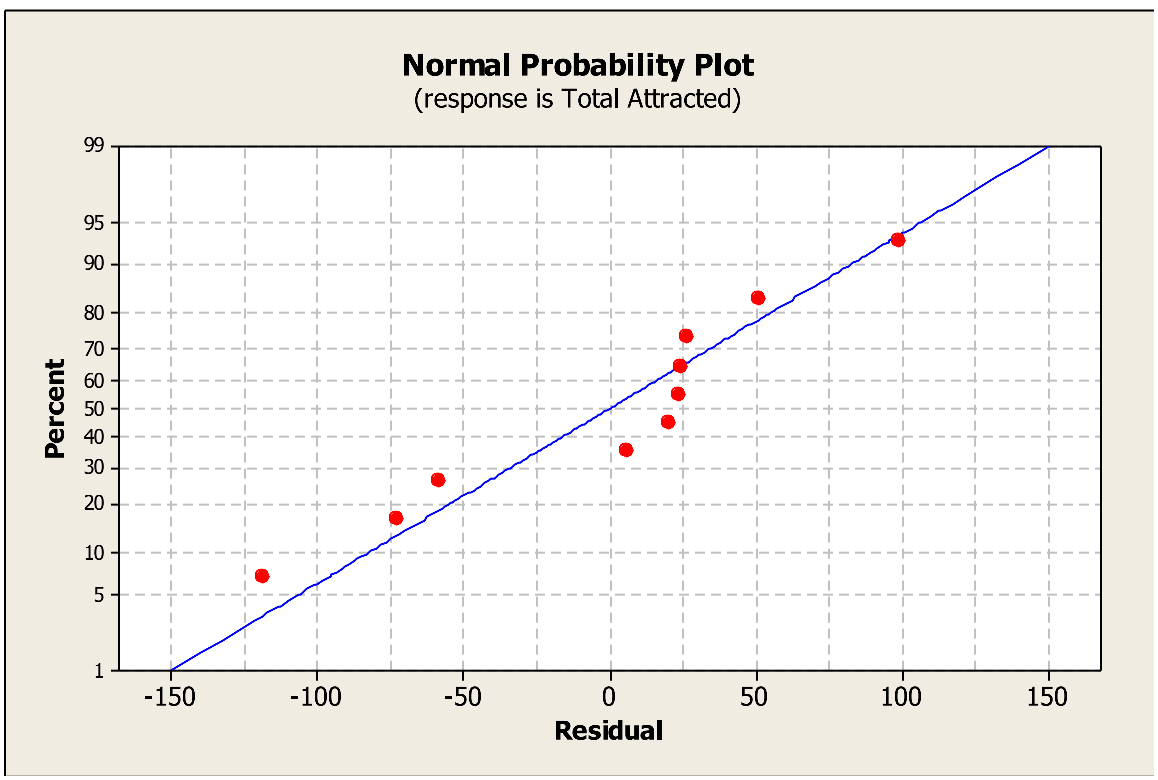
ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 538186.9 | 538186.9 | 321.9862 | 9.53873E-08 |
| Residual | 9 | 15043.14 | 1671.459 | | |
| Total | 10 | 553230 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Employees | 5.889096533 | 0.328193556 | 17.94397 | 2.36E-08 |

## Classes


y = 11.787x + 57.562
R² = 0.4074
Attracted Vehicles
Classes
350
300
250
200
150
100
50
0
0
5
10
15
20
25


Normal Probability Plot
(response is Total Attracted)
Percent
Residual
99
95
90
80
70
60
50
40
30
20
10
5
1
-150
-100
-50
0
50
100
150


SUMMARY OUTPUT

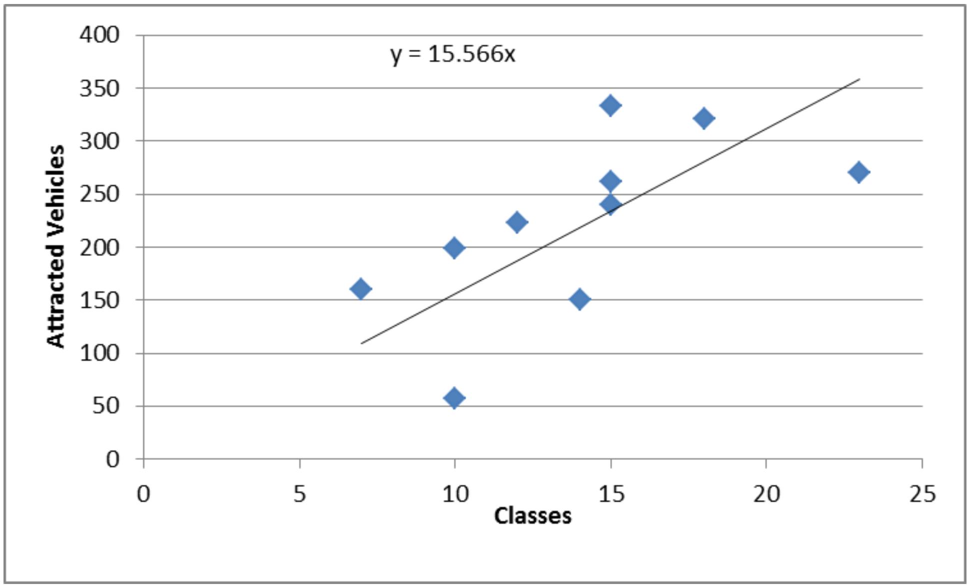
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.6383 |
| R Square | 0.407426 |
| Adjusted R Square | 0.333355 |
| Standard Error | 68.33923 |
| Observations | 10 |

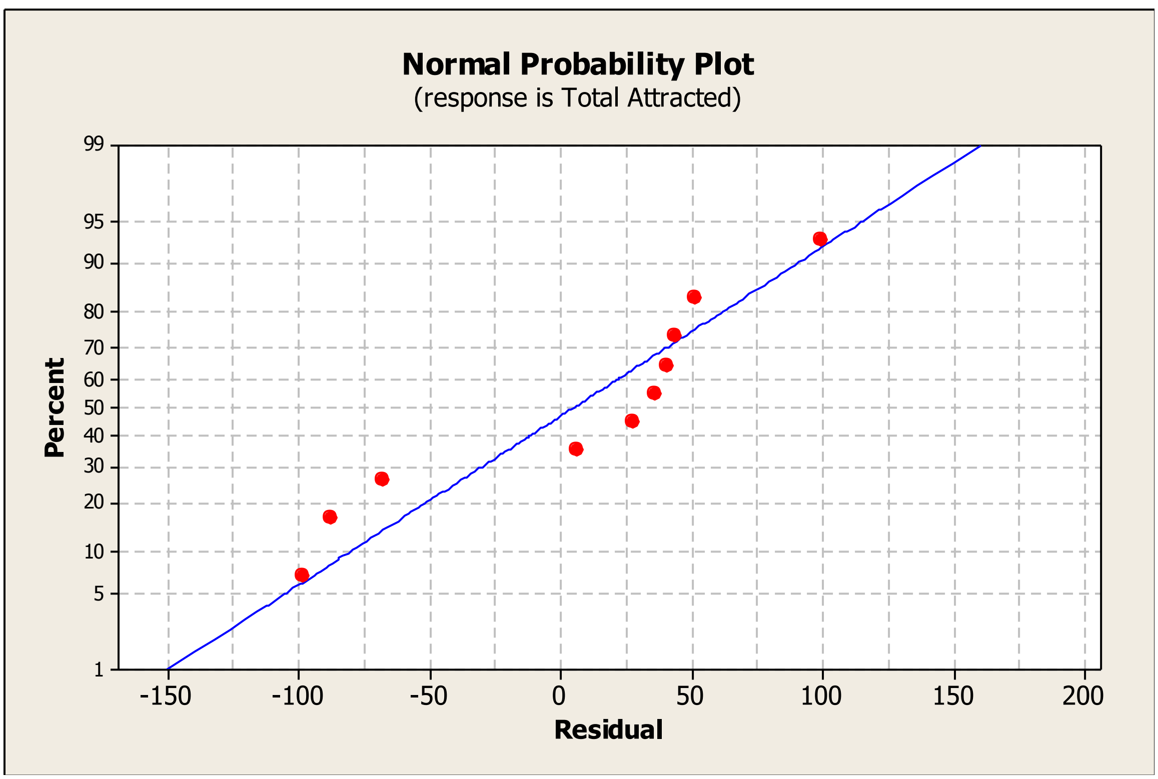
ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 25688.4 | 25688.4 | 5.500432 | 0.047025011 |
| Residual | 8 | 37362 | 4670.251 | | |
| Total | 9 | 63050.4 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 57.56192537 | 73.12435749 | 0.787179 | 0.453864 |
| Classes | 11.78691184 | 5.025758712 | 2.3453 | 0.047025 |

**<u>Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below</u>**




SUMMARY OUTPUT

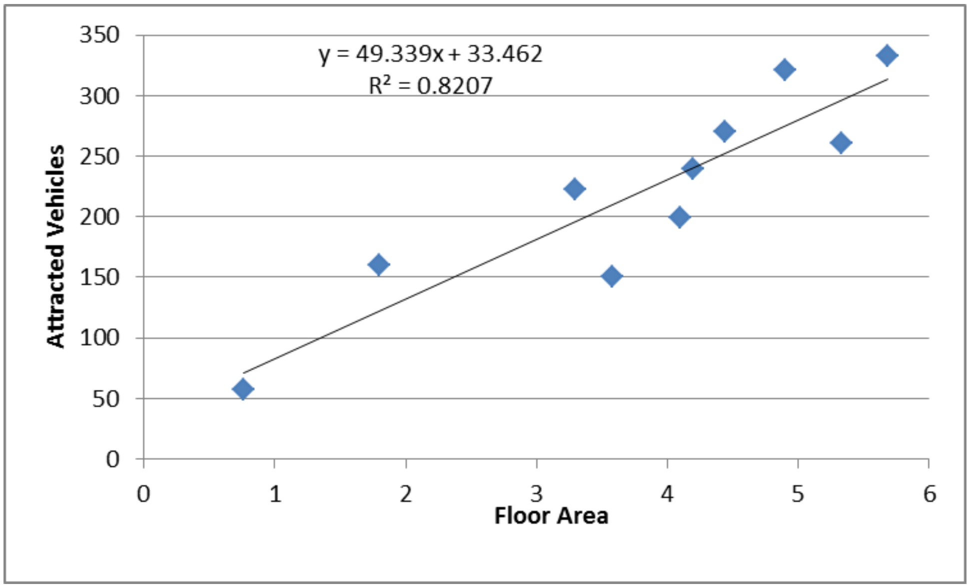
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.96293 |
| R Square | 0.927235 |
| Adjusted R Square | 0.816124 |
| Standard Error | 66.8796 |
| Observations | 10 |

ANOVA

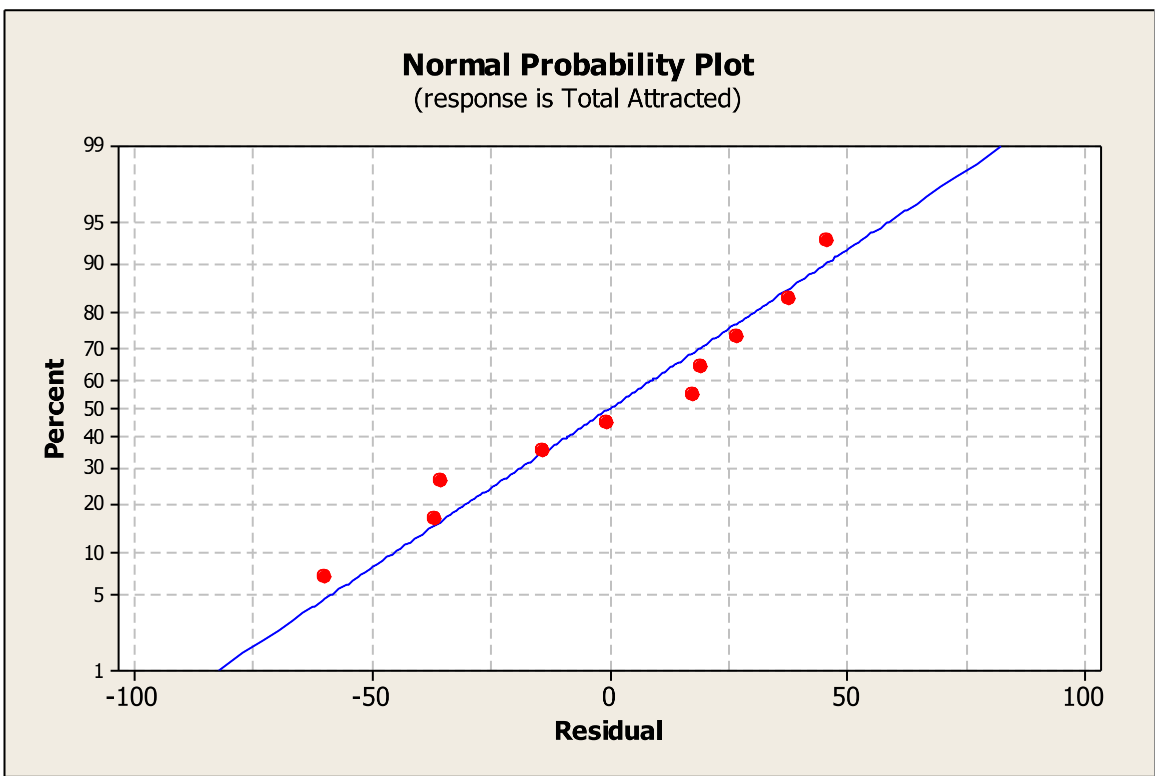
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 512974.1 | 512974.1 | 114.6854 | 5.07809E-06 |
| Residual | 9 | 40255.93 | 4472.881 | | |
| Total | 10 | 553230 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Classes | 15.5663675 | 1.453560871 | 10.70913 | 2.02E-06 |

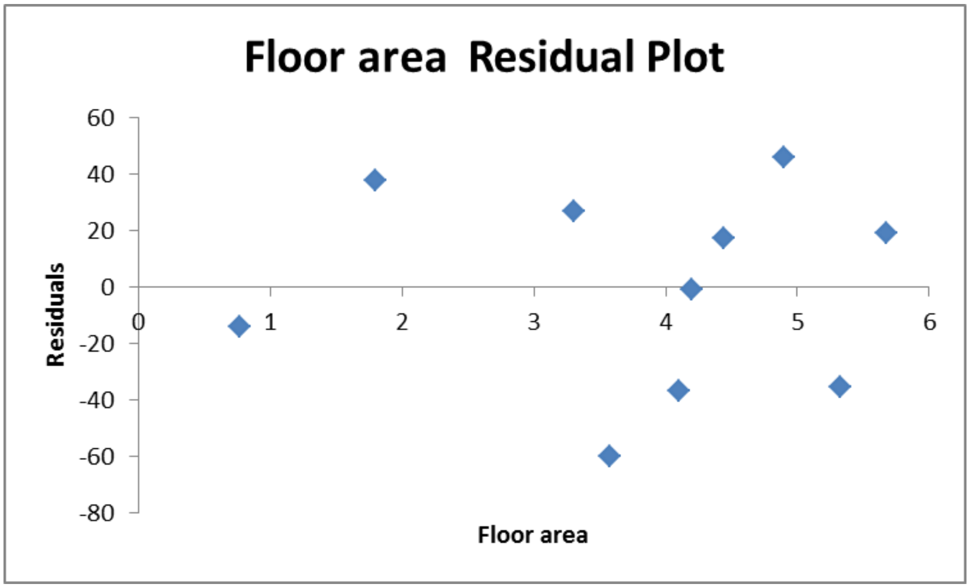
## Floor Area



y = 49.339x + 33.462
R² = 0.8207
Attracted Vehicles
350
300
250
200
150
100
50
0
0
1
2
3
4
5
6
Floor Area

Normal Probability Plot
(response is Total Attracted)
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
-100
-50
0
50
100
Residual




SUMMARY
OUTPUT

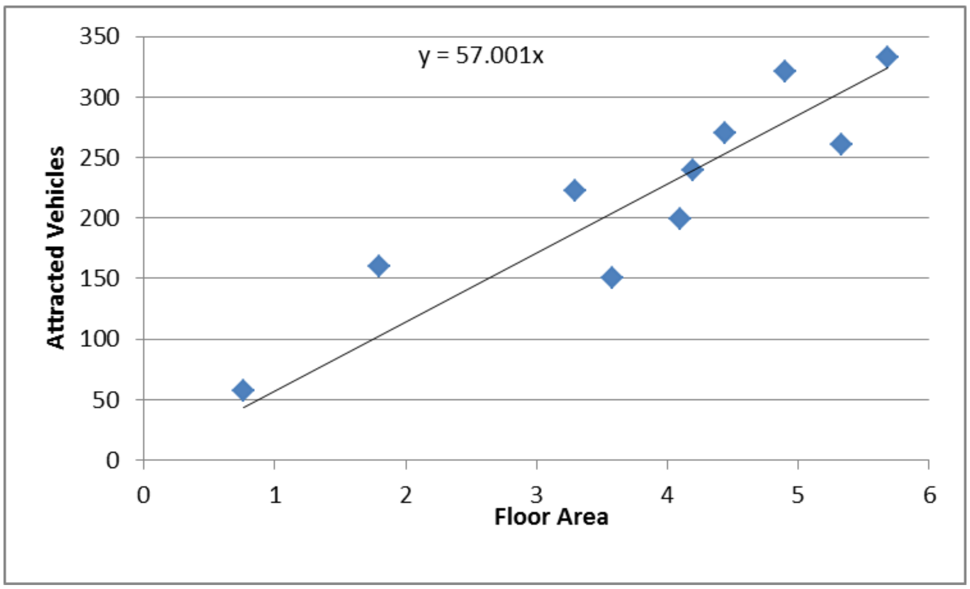
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.905907 |
| R Square | 0.820667 |
| Adjusted R Square | 0.79825 |
| Standard Error | 37.59495 |
| Observations | 10 |

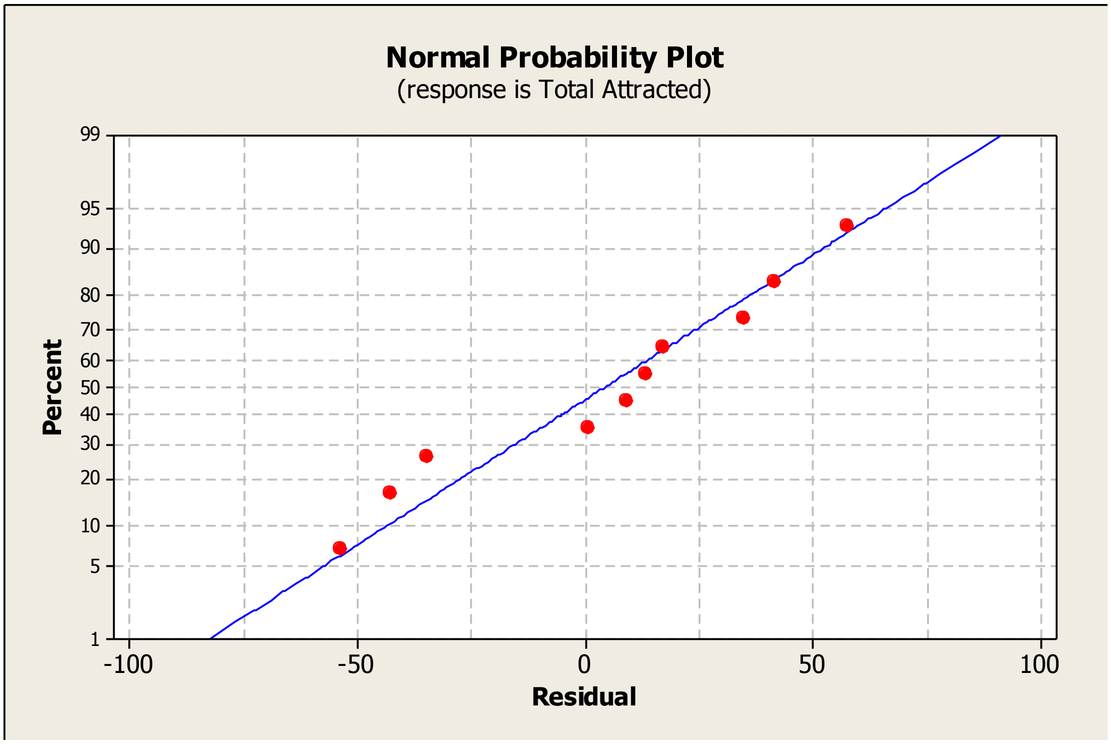
ANOVA

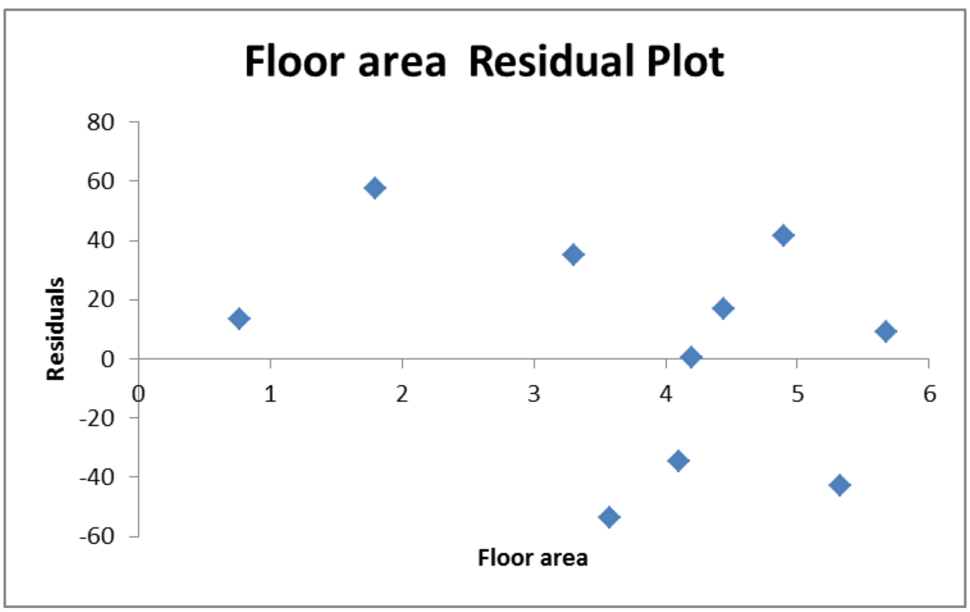
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 51743.36 | 51743.36 | 36.60966 | 0.000305714 |
| Residual | 8 | 11307.04 | 1413.38 | | |
| Total | 9 | 63050.4 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 33.46213007 | 33.25850735 | 1.006122 | 0.343815 |
| Floor area | 49.33917984 | 8.154439059 | 6.050592 | 0.000306 |

**<u>Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below</u>**




Normal Probability Plot
(response is Total Attracted)
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
-100
-50
0
50
100
Residual


Floor area Residual Plot
Residuals
80
60
40
20
0
-20
-40
-60
0
1
2
3
4
5
6
Floor area

SUMMARY OUTPUT

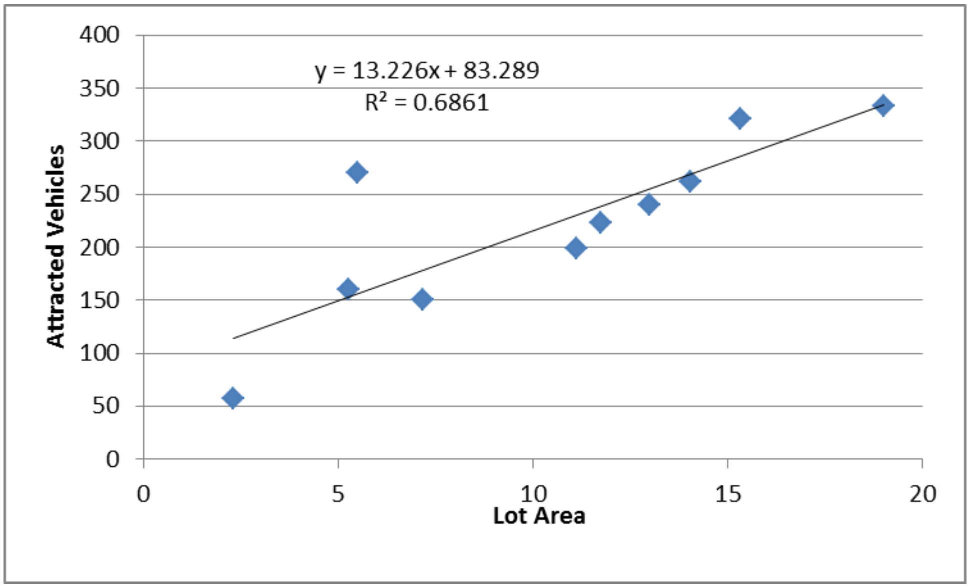
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.988421 |
| R Square | 0.976976 |
| Adjusted R Square | 0.865865 |
| Standard Error | 37.62059 |
| Observations | 10 |

ANOVA

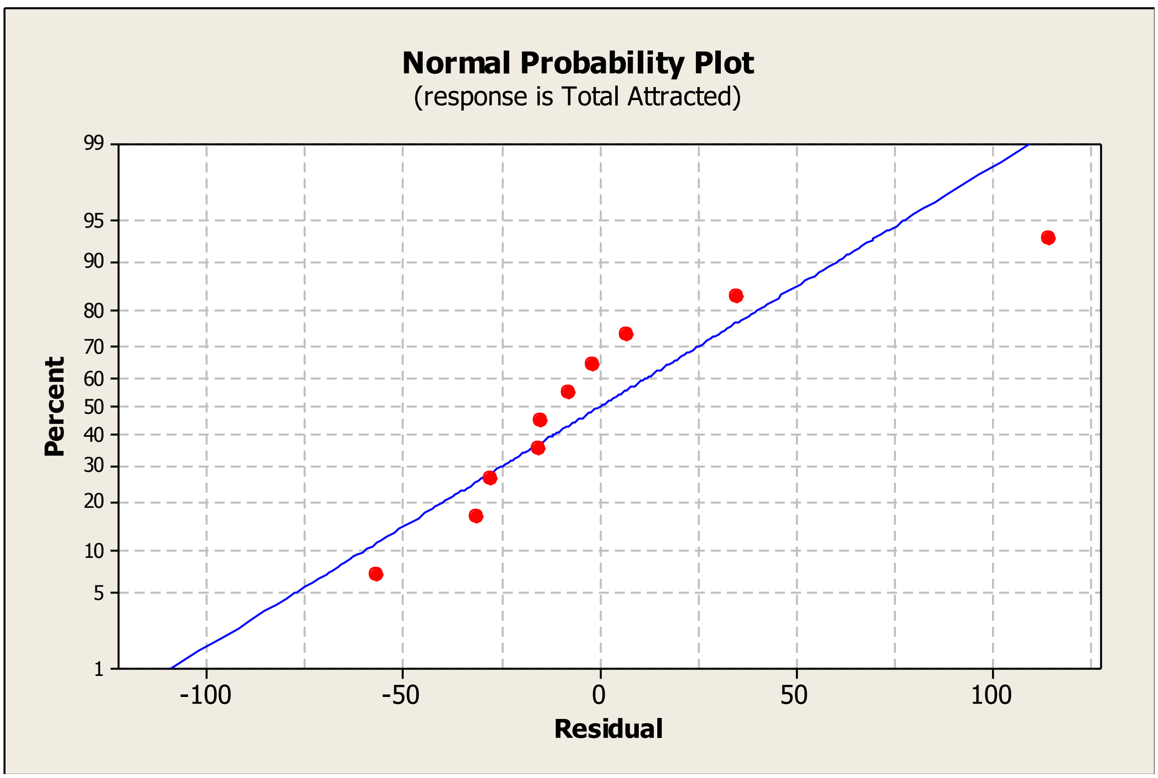
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 540492.2 | 540492.2 | 381.8899 | 4.88704E-08 |
| Residual | 9 | 12737.78 | 1415.309 | | |
| Total | 10 | 553230 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Floor area | 57.00147067 | 2.916869198 | 19.542 | 1.11E-08 |

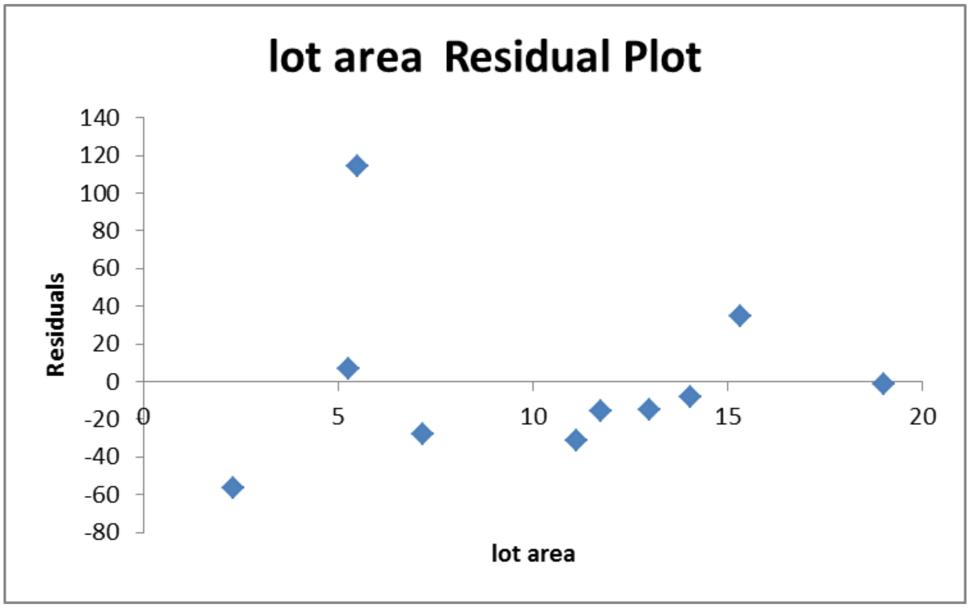
## Lot Area



y = 13.226x + 83.289
R² = 0.6861
Attracted Vehicles
Lot Area
400
350
300
250
200
150
100
50
0
0
5
10
15
20

Normal Probability Plot
(response is Total Attracted)
Percent
Residual
99
95
90
80
70
60
50
40
30
20
10
5
1
-100
-50
0
50
100

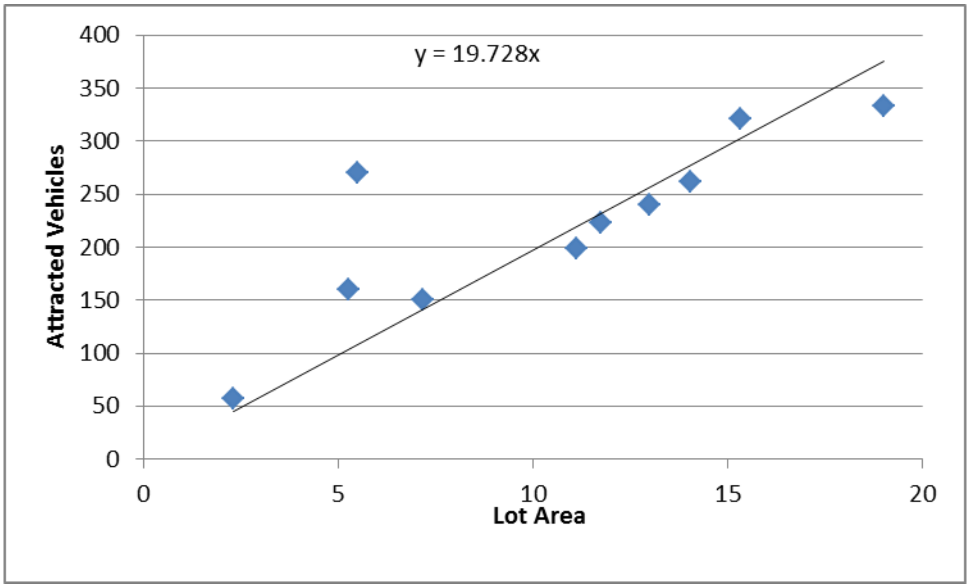


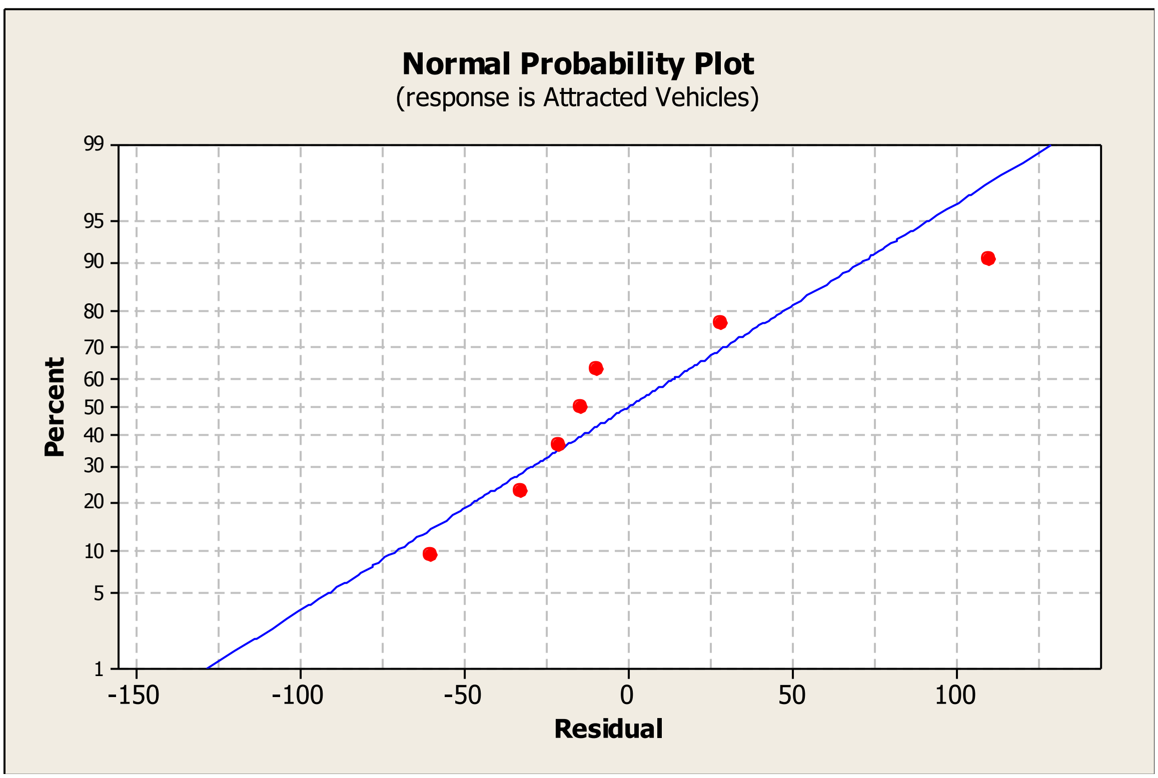

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.828337 |
| R Square | 0.686141 |
| Adjusted R Square | 0.646909 |
| Standard Error | 49.73544 |
| Observations | 10 |

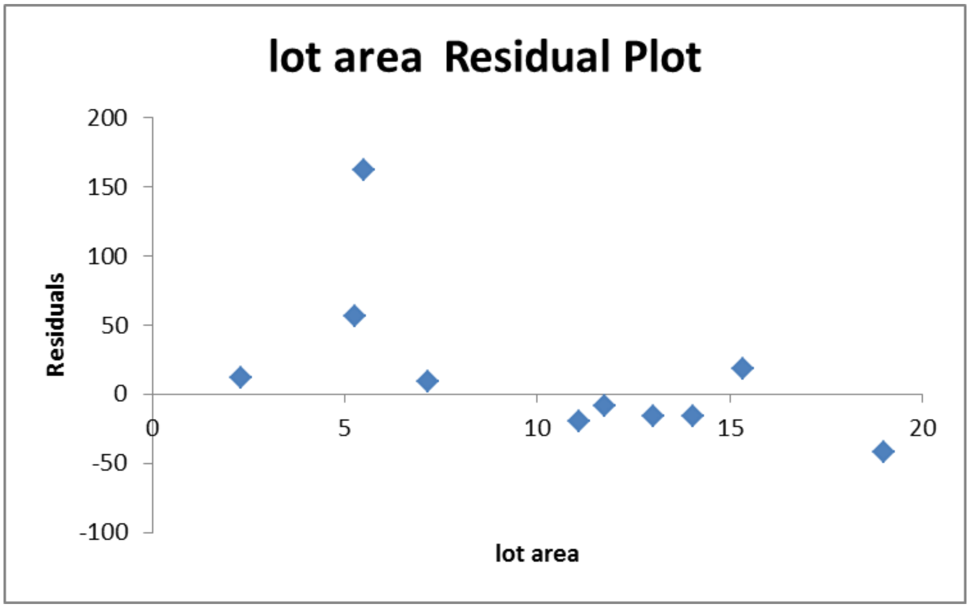
ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 43261.49 | 43261.49 | 17.48918 | 0.003071167 |
| Residual | 8 | 19788.91 | 2473.614 | | |
| Total | 9 | 63050.4 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 83.28921881 | 36.57884453 | 2.276978 | 0.052318 |
| Lot area | 13.22646822 | 3.162708089 | 4.182007 | 0.003071 |


y = 19.728x
Attracted Vehicles
400
350
300
250
200
150
100
50
0
0
5
10
15
20
Lot Area


Normal Probability Plot
(response is Attracted Vehicles)
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
-150
-100
-50
0
50
100
Residual




SUMMARY OUTPUT

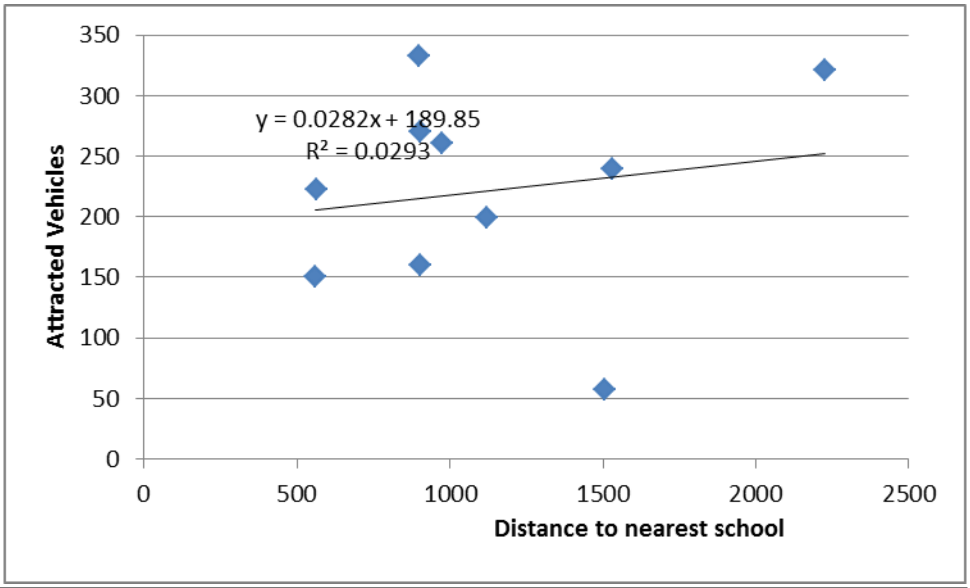
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.970077 |
| R Square | 0.941049 |
| Adjusted R Square | 0.829937 |
| Standard Error | 60.19753 |
| Observations | 10 |

ANOVA

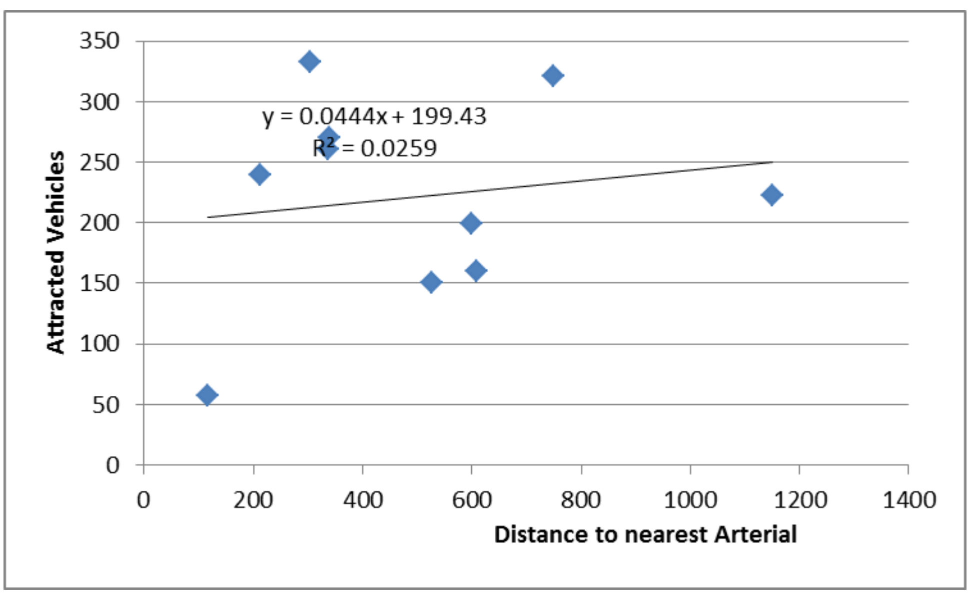
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 520616.3 | 520616.3 | 143.6682 | 2.1628E-06 |
| Residual | 9 | 32613.68 | 3623.742 | | |
| Total | 10 | 553230 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Lot area | 19.72822518 | 1.645916 | 11.98616 | 7.78E-07 |

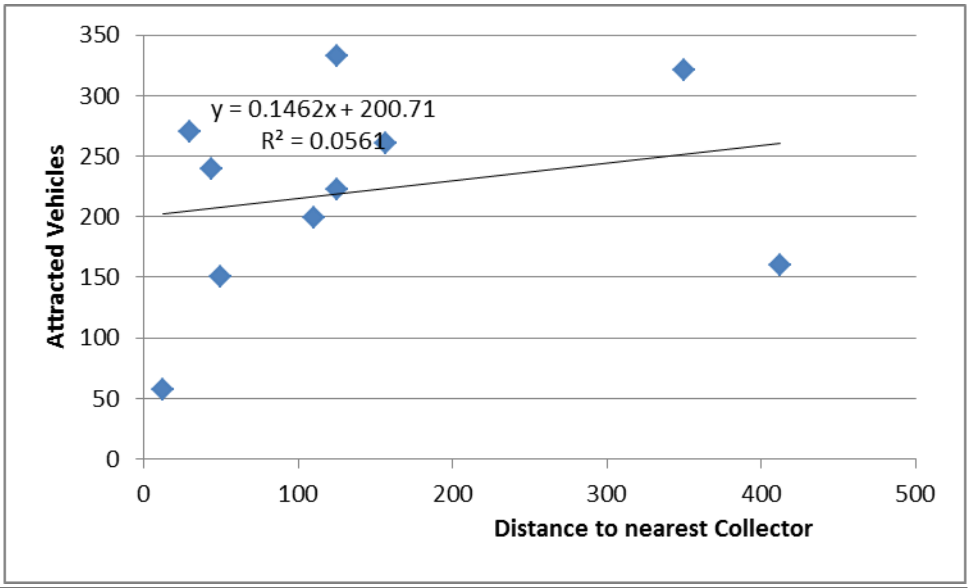
## Distance to nearest school



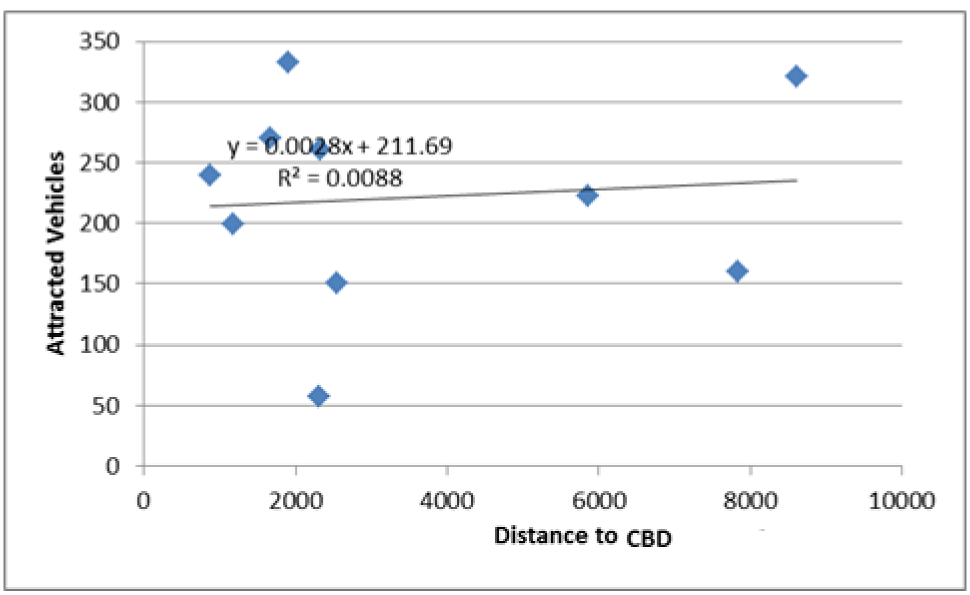

## Distance to nearest arterial



## Distance to nearest collector

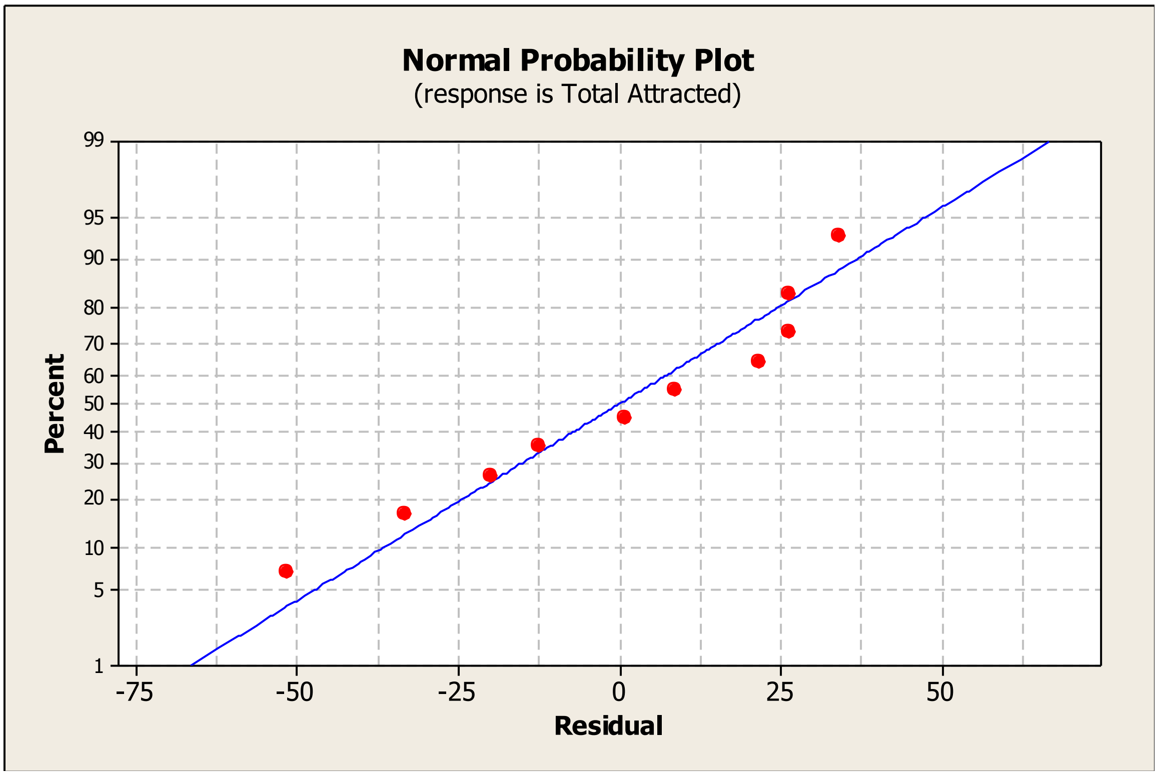


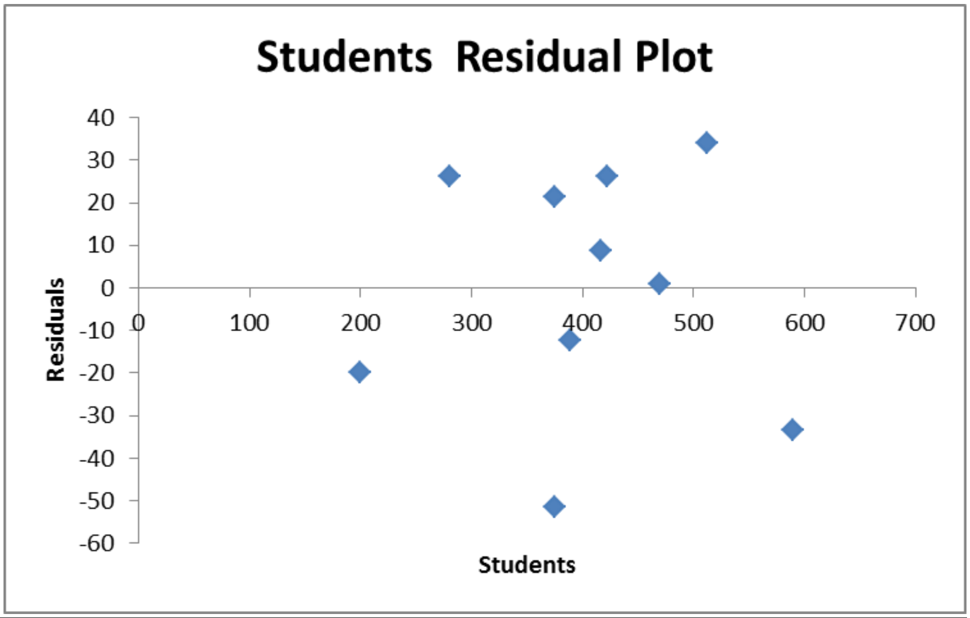

## Distance to CBD



## Multiple linear regressions using all of 10 schools

**Attracted vehicles = -65.30+0.711*Students**






SUMMARY
OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.939635 |
| R Square | 0.882914 |
| Adjusted R Square | 0.868278 |
| Standard Error | 30.3775 |
| Observations | 10 |

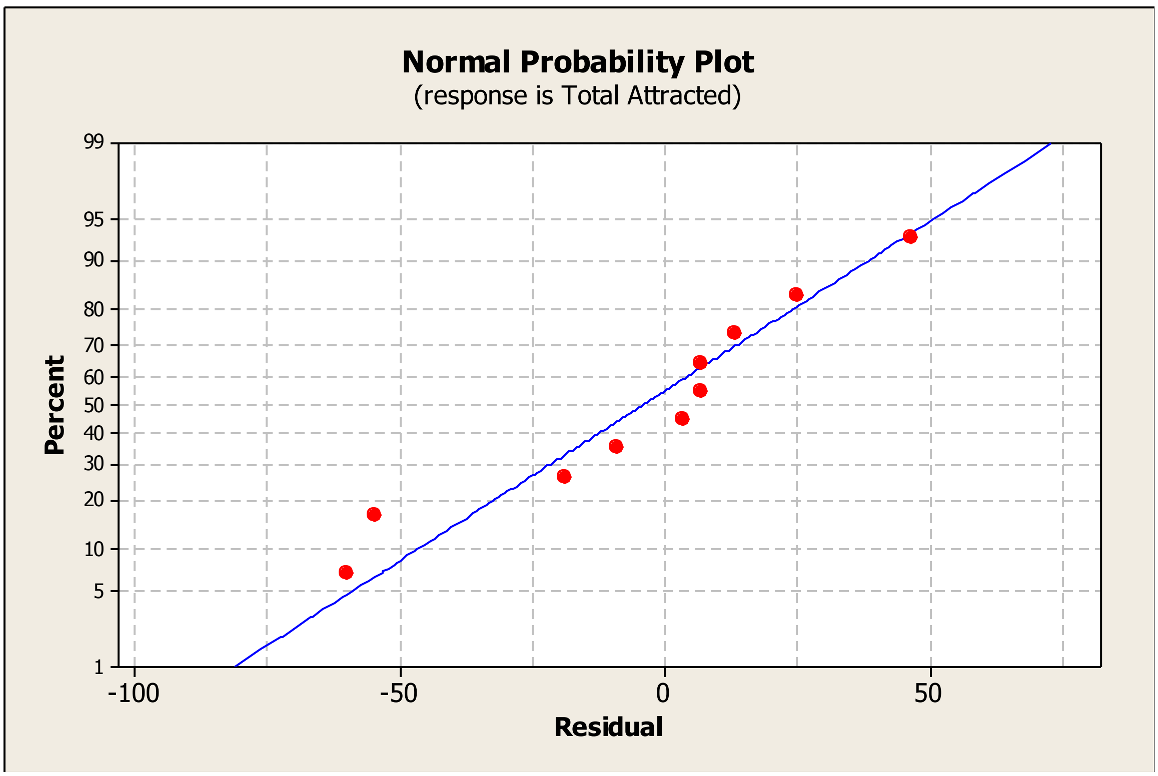
ANOVA

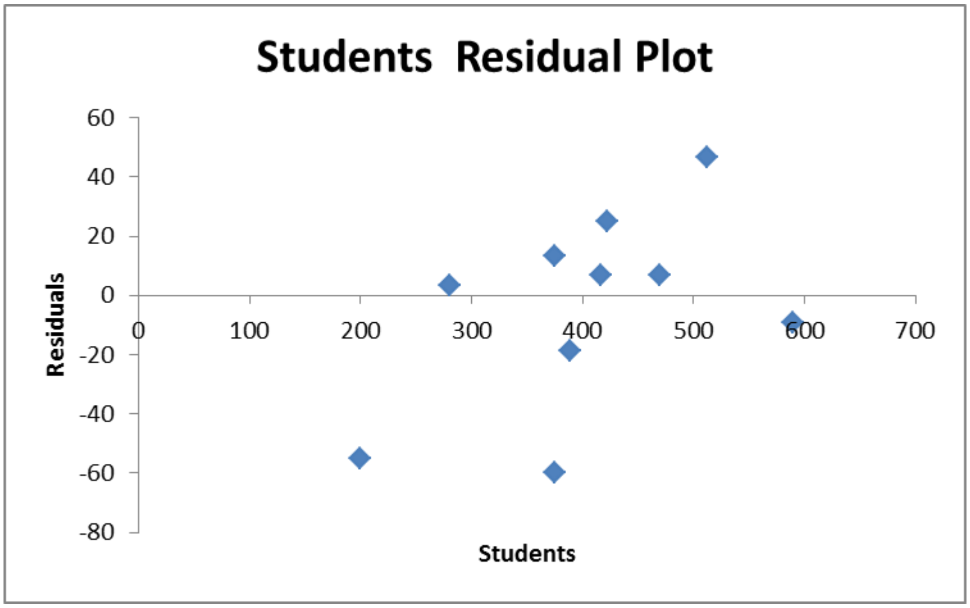
| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 55668.06 | 55668.06 | 60.32567 | 5.39896E-05 |
| Residual | 8 | 7382.338 | 922.7922 | | |
| Total | 9 | 63050.4 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | -65.292085 | 38.14126878 | -1.71185 | 0.125284 |
| Students | 0.71139475 | 0.091592428 | 7.76696 | 5.4E-05 |

**<u>Since constant has a high P-value, the intercept was forced to be zero as shown in the second trial below</u>**

**Attracted vehicles = 0.56*Students**






SUMMARY OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.990842 |
| R Square | 0.981768 |
| Adjusted R Square | 0.870657 |
| Standard Error | 33.47721 |
| Observations | 10 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 543143.5 | 543143.5 | 484.6364 | 1.91405E-08 |
| Residual | 9 | 10086.51 | 1120.724 | | |
| Total | 10 | 553230 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A |
| Students | 0.559656719 | 0.025422233 | 22.01446 | 3.89E-09 |

# VITAE

| | | |
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